



Campbell - 1 ca. 101-4

10
P. L. L. L.

~~Dr. with Hitchcock's~~
~~24 Summer~~ Place

~~St. Louis~~

~~Dr. Coomins~~
~~Kitchell~~
~~Zetlinburgh.~~



19
Dr. Comings
No 37
Washington



General Board of Lunacy,
Edinburgh, 15 Nov 1877

OF LOCHABER.

Dear Doctor,

I fancy Mr.

Campbell will wait

for Mr. William Home's

shot N^o. 2. As soon

as ever it comes to me,

I shall send

it on to Knollan.

EDDERBURN, LL.D.

EDINBURGH, VOL. XXVII.

EDINBURGH:
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MDCCLXXVI.

In the meantime
I send you sheet
N^o: 1. I should
have sent it at
once to Mr
Campbell, but I do
not know on what
spot of earth that
wanderer rests at
present. The post

St. Campbell
N^o: 1
Washington



office will profit.

Most sincerely yours

Wm. Mitchell OF LOCHABER.

P.S.

I gave Mr Melne
some your full
address & requested
him to send the
papers to Kinellan,
but he says he

EDDERBURN, LL.D.

EDINBURGH, Vol. XXVII.

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MDCCLXXVI.

is not sure of your
address. Some memory
of your being a
wanderer too no
doubt has been
battering his
brain. fu.

2 St. James St
No 234
Eastington St



Dilne Garden
Coldstream

Nov 14
77

Dear Dr - Mitchell

I delayed
receiving of note about my
Lochaber paper, which Dr
Cummins wishes to send to
Mr Campbell, for this reason.

Since my paper was
published in the Roy. Society
Transactions, an additional
Memoir on the same subject
was read last Session by me,
and it has actually been
printed, though the Volume

ON THE

DS OF LOCHABER.

BY

ME OF WEDDERBURN, LL.D.

FROM THE

TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, Vol. XXVII.

EDINBURGH:

PRINTED FOR THE SOCIETY BY NEILL AND COMPANY.

MDCCLXXVI.

containing it has not yet
been given out to members -
i on receipt of yr note, I
ad. wrote to the Ministers (Will & Co.)
to know if they get the 25
of copies, who are the proprietors of
wa authors, that I might send a
one with the former one to you
for Mr Campbell's acceptance

The Ministers however have
not yet answered my letter -
Perhaps they are consulting Messrs
the Society's Secretary
(Belfast)



Wm Campbell
No 24 York
Belfast

Meanwhile, & in consequence
of the note received to-day, I
forward to you a copy of the
former Memoir, as I am
not sure of Dr Cummins
address

ON THE

DISSEMINATION OF
THE DOCTRINE OF
THE RIGHTS OF MAN.

Believe me
Yours very truly,

David Mitchell

D. A. Mitchell

In the proceedings of last
Session, ~~has~~ already published
& distributed, there is an abstract of
my last paper. A copy may be
got at the Society's Library

BY

WILLIAM WEDDERBURN, LL.D.

FROM THE

TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, Vol. XXVII.

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o. H. Campbell
No. 337, 10th
Kearney Street



ON THE
PARALLEL ROADS OF LOCHABER.

BY
DAVID MILNE HOME OF WEDDERBURN, LL.D.

FROM THE
TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, Vol. XXVII.

EDINBURGH:
PRINTED FOR THE SOCIETY BY NEILL AND COMPANY.
MCCCCLXXVI.

XXVII.—*On the Parallel Roads of Lochaber.* By DAVID MILNE HOME, LL.D.
(Plates XLI., XLII., XLIII.)

(Read 15th May 1876.)

I. The Parallel Roads of Lochaber have presented to geologists a problem, which is still unsolved. Dr MACCULLOCH, about sixty years ago, when President of the Geological Society of London, first called attention to these peculiar markings on the Lochaber Hills, by an elaborate Memoir afterwards published in that Society's Transactions. He was followed by Sir THOMAS DICK LAUDER, who in the year 1824, read a paper in our own Society, illustrated by excellent sketches. His paper is in our Transactions. The next author who attempted a solution was the present Mr CHARLES DARWIN. He maintained that these Roads were sea-beaches, formed, when this part of Europe was rising from beneath the Ocean. He was followed by Professor AGASSIZ, Dr BUCKLAND, CHARLES BABBAGE, Sir JOHN LUBBOCK, ROBERT CHAMBERS, Professor ROGERS, Sir GEORGE M'KENZIE, Mr JAMIESON of Ellon, Professor NICOL, Mr BRYCE of Glasgow, Mr WATSON, and Mr JOLLY of Inverness. Sir CHARLES LYELL, though he wrote no special memoir, treated the subject pretty fully in his works, giving an opinion in support of the views of AGASSIZ.

I took some little part myself in the discussion, having in the year 1847 read a paper in this Society, which was published in our Transactions.

During the last five or six years, there has been an entire cessation of both investigation and discussion, in consequence probably of a desire to await the publication of more correct maps of the district, which at the request of the British Association for the Advancement of Science, the Ordnance Survey Department undertook.

These Ordnance Maps were not available to the public before last Autumn, when with a copy of these in my hand, I went back to the district, to see whether any more distinct views would occur to me, than those I had obtained thirty years ago, when the late ROBERT CHAMBERS and I examined the Parallel Roads together.

II. Perhaps, before stating the results of my recent visit, it may be convenient for those who happen not to be well acquainted with the subject, that I briefly state the problem to be solved, and the different solutions which have been suggested.

There are 3 or 4 valleys in Lochaber, to the North of Ben Nevis, each from 10 to 15 miles in length, and having a depth of from 500 to 1000 feet, the sides of which are deeply notched by shelves called "*Parallel Roads*"; so called probably, because being horizontal, they are parallel to one another, and consist of spaces, so broad and regular, that a cart might be driven on them.*

In Glen Gluoy, whose mouth opens on Loch Lochy towards the West, there are two shelves, at a height, one of 1165, the other of 964 feet above the sea.

In Glen Roy, whose mouth also opens towards the West, there are on each side of the Glen, for a considerable part of the valley, 3 shelves, at these respective heights above the sea (beginning with the highest)—1149, 1068, and 856 feet.

In Glen Spean, which in its lower part joins Glen Roy, there is only one well-defined shelf, 856 feet above the sea. It is a continuation of the lowest in Glen Roy.

Dr MACCULLOCH was too cautious to offer a decided opinion regarding the origin of the shelves. He gave a minute and correct account of the phenomenon:—but he advanced no positive explanation, confessing his inability to give any. He only suggested general views, and farther inquiry.

Sir THOMAS DICK LAUDER thought that the Roads had been formed by lakes, but he was much at a loss to account for the removal of the Barriers by which the lakes had been retained.

Mr DARWIN, in his paper, thought the Barrier difficulty so great, that he deemed no other explanation possible, than that the "*Roads*" were *sea-beaches*. His theory was adopted by the late ROBERT CHAMBERS, Professor NICOL, Mr WATSON, and others.

Professor AGASSIZ and Dr BUCKLAND accepted the theory of Lakes, and suggested that the Lakes had been dammed up by Glaciers; a view taken by a majority of subsequent inquirers, and in particular by Sir CHARLES LYELL, Mr JAMESON of Ellon, and Mr JOLLY of Inverness.

III. Such being the nature of the problem and the various attempts to solve it, let me now briefly indicate the view which I have taken. It is much the same as that explained in my former Memoir: But I expect now to be able to rest it on a wider basis of facts, and to support it on stronger grounds.

I concur with the great majority of observers, in attributing the formation of the shelves to Lakes. My reasons are these,—

1st. In three of the Glens, the existence of an old River Channel has been ascertained and traced, by which in each Glen, the surplus Waters of the Lakes were discharged.

* In *Glen Gluoy* (as Sir THOMAS DICK LAUDER states) the highest shelf has a width of 100 yards. In *Glen Spean* Shelf 4, above Inverlair House, has a width of 20 yards. (See fig. 17, p. 51.) In *Glen Gluster*, on the side next Craig Dhu, this same shelf has a width of nearly 100 yards, as is shown on the Ordnance Survey 6-inch Map.

Thus the Lake which filled Glen Gluoy at its highest shelf, reached the summit level between that Glen and Glen Roy; and at that summit level an old River Channel was discovered by ROBERT CHAMBERS and me, leading down to Glen Roy, at the timewhen Glen Roy was occupied by a lake, not only when this lake was at its highest level of 1149 feet above the sea, but also when the Glen Roy Lake sank to the next level of 1068 feet above the sea.*

So also at the summit level between Glen Roy and the Valley of the Spey, there is a flattish hollow, exactly corresponding in level with the highest shelf in Glen Roy, over which the Lake in Glen Roy when at its height of 1149 feet above the sea could discharge its surplus waters.

* As this is a point of some importance, it is only fair to state, that a very experienced observer, Professor NICOL of Aberdeen, does not admit that there is evidence of a River Channel from any one Glen into another Glen. He says ("London Geol. Socy. Journal," May 12, 1869, page 284) "I examined the various passes carefully, and found that whilst in none of them was there the slightest trace of an ancient river, in all there were distinct indications of the former existence of a narrow Sea Strait." The valley by which the Gluoy Lake is assumed to have drained into Glen Roy is very narrow, and encumbered with detritus from the hills on the sides. The summit level is flat and marshy, and it appeared to me considerably below the level of the line (*i.e.*, the 'Road'?). On the other hand, a line of stones, as if washed out of the detritus, appeared to show that the sea or loch, had extended quite through the Strait. I observed no indication of any stream of water, larger than the present small rivulet, having ever been there."

In answer to these statements, I give the following Extracts from the Notes made by me on the occasion of my visit to the place with ROBERT CHAMBERS, in September 1846.

"At the head of Glen Gluoy, Shelf 1 almost disappears in the Moss. It is however faintly visible on the North side, about 1 or 2 feet above the Moss, running towards Glen Turret. The Moss I found to be $5\frac{1}{2}$ feet thick above Boulder Clay. About $1\frac{1}{2}$ miles to Eastward, found rocks in middle of Channel, much worn and smoothed,—their rough edges or faces all pointing Eastward, *i.e.*, towards Glen Roy. This is near Glen Turret, and about the place where traces of Shelf 1 disappear. About 8 or 10 feet above these smoothed rocks there are other rocks which present no appearance of smoothing.

"At the side, there are low grassy knolls or hummocks apparently marking edge of a River Course,—which here 40 yards wide.

"Apparently Gluoy Lake continued to discharge, whilst Roy dropped from Shelf 2 to 3, hence additional cutting power given to Gluoy Stream;—and accordingly there is a deep and rocky ravine, down to Glen Turret.

"Measured with ROBERT CHAMBERS (who first drew my attention to fact) depression of Shelf 2 in Glen Roy below Shelf 1, and found that by *Spirit-levelling*, it was 29 feet; by *Synpysometer* 35 feet; by *Barometer* 11 feet.

"Visited next, head of Glen Roy, in upper Glen Roy. Interesting to observe how uniformly the smooth surfaces of rocks are to West, the rough faces to East." (Notes p. 47).

The following applies to the Glen Glaster old River course.

"Discovered debouche of Lake No. 3 in Glen Glaster. A Shelf on both sides runs up to Col, at a level coincident with Moor there.

"At this place, rocks appear above moss. These are about middle and lowest part of flat.—Evidently, water has rushed over these rocks from West: for their round and smooth faces are to West, their rough faces to East. They form a Channel sloping down towards Loch Laggan for about a mile. By existing burn, they can't have been rounded, as this burn, very small, and 20 feet below them. These rocks occupy a breadth of from 30 to 40 feet, and have evidently occupied bed of a stream, exceeding that width. Walked along this supposed ancient water-course for about a mile, and saw that it extended down towards Loch Laggan, as far as eye could reach. Probably Loch Laggan then stood at level of Shelf 4, discharging itself at Mukkoul, as it continued to do, when Lake Roy sunk to Shelf 4.

"No sand or gravel in this old Water-course, but numerous granite boulders, very spherical.

"Remnants of sloping haughs on each side, evidently formed by old River when in flood,—with precipitous cliffs beyond these haughs,—indicating height to which floods reached."

So also when this Lake sank to the next "Shelf" or "Road" (1066 above the sea), the surplus waters at that level were discharged by a River Channel discovered in Glen Glaster, which led to Loch Laggan at a place called the Rough Burn, and where there is now a great accumulation of materials having all the appearance of a Delta; the Delta being exactly at the place where one would be formed by a river flowing into a lake, at the height of 856 feet above the sea.

So also, with regard to this lake which formed the shelf at 856 feet above the sea; there is at the N. E. end of Loch Laggan, at a place called Mukkoul, an old river channel, which is at the very spot, and level, suitable for carrying off the surplus waters of the Lake. The River Pattaig now runs here into Loch Laggan. But this river had evidently, at a former period, flowed in a different direction, viz., towards the eastward, when the lake stood about 38 feet higher than at present. Last autumn, I walked up the



Fig. 1.

Beds of gravel and sand, from 60 to 70 feet high, in Glen Spean (near Tulloch), cut through by small streams from the adjoining hills.

banks of this River, and at about a mile from its debouche into Loch Laggan, I found the old channel, now dry, about 25 feet above the present stream, running Eastward towards the valley, through which Loch Laggan sent its surplus waters into Strath Spey,

From the Ordnance Maps, it will be observed, that this last mentioned shelf runs along the north side of Glen Spean towards the lower end of the Glen, where it encircles some rocky knolls. Between these knolls and the hill called "*Craig Dhu*," there is a summit level or col separating Glen Roy from Glen Spean. As these cols are generally instructive, I examined this one, and was not disappointed. It is about 20 feet below the level of Shelf 4, and con-

sists of a rocky ridge formed by the upturned edges of Mica Slate strata. These strata have been worn down apparently by water flowing over them from the Glen Roy side, their smooth faces being on that side, their rough faces on the side next Glen Spean. On the shelf itself there are multitudes of large well washed pebbles and boulders. When the lake stood at the level of the shelf, discharging at Mukkoul, the water then occupying Glen Roy would flow towards Mukkoul, and one of the passages would be the narrow and shallow strait just referred to.

In Glen Roy, and at many other places, the middle shelf is seen to have been deeply cut through by burns, whose sides expose the material of the old beach and of the lake bottom. Thus at Dalrioch and on the N. E. shoulder of Craigh-Dhu, the old lake bottom consists of fine clay, or mud, horizontally stratified and laminated,—evidence of the stillness and depth of the water in which the sediment had been deposited. At the spot last mentioned, there are cliffs of sandy mud from 40 to 60 feet high. These beds of mud are occasionally covered by beds of stratified sand.

In Glen Collarig, the lowest shelf on Bohuntine Hill is crossed and cut through by a burn. The material there also consists of sandy mud with small boulders and pebbles.

At Inverlair and Fersit, (near Loch Treig), there are large portions of the old bottom of the lake still extant, consisting of gravel cliffs from 50 to 60 feet in height. Great beds of sand occasionally occur in these gravel deposits. Fig. 1, page 4, is an attempt to show this old lake bottom cut through by streams from the adjoining hill.

These facts supplied some of the grounds on which the lake theory rested. Other arguments will be noticed, when I refer more particularly to the sea theory.

Meanwhile, I may allude to another fact recently ascertained which greatly strengthens the Lake hypothesis.

Our colleague the Revd. Mr BROWN has in one of the shelves (viz., the lowest of the three in Glen Roy, Shelf 4) discovered fresh water *Diatoms*. They could not have existed where he found them if the shelves were marine ("Roy. Soc. Proceedings," 2d March).

IV. The next point for consideration is by what means the lakes were kept up to the height of the shelves, in the absence of any appearance at present of Barrier or Blockage.

In the lower part of Glen Roy the bottom of the valley is about 800 feet below the highest shelf, and the valley is about a mile wide.

How then were the lakes kept in ?

1. To understand clearly this part of the problem, it is proper to observe

in what part of the glens the shelves cease, for there, or near that part, the blockage whatever it was, most probably existed.

In Glen Roy, as will be seen from the map annexed (Plate XLI.), the highest shelf, No. 2, exists in the upper part of the glen, on both sides, but does not come farther down the glen than a certain point on each bank. These two points, it will be observed, are nearly opposite to each other. Here, therefore, the lake is generally assumed to have terminated, when it stood at its highest level, and here a blockage of some kind must be sought for. Let it be also noticed, that this shelf, No. 2, enters the side valley, called Glen Collarig, through a hollow or depression called the "Gap," *but only for a certain distance*;—and there, another blockage of some kind must have existed, to account for the stoppage of the shelf.

When the Lake sank to its next, the 1068 feet level (Shelf 3), it formed a beach line not only in the upper part of Glen Roy, but in a lower part, *i.e.*, in a part about one quarter of a mile lower down the Glen than the spot where No. 2 shelf stopped. The blockage, or a part of it, to allow this, must have been lowered 81 feet,* and must have occupied a situation further south. This lower shelf, No. 3, is traceable into Glen Glaster, and approaches the col where there is the old river course, by which the lake, when at that level, overflowed towards what is now called the Rough Burn into Glen Spean.

This lower shelf, continues in Glen Roy on both sides, and, like Shelf 2, stops at certain points, as may be seen on the map, nearly opposite to one another.

This lower shelf also goes through the gap into Glen Collarig;—and it goes a little beyond the place where shelf No. 2 stopped. Here, therefore, as in Glen Roy, something occurred to allow the lake in Glen Collarig to reach a little farther south, and to be kept up there at that lower level. To allow of this extension of the lake, both in Glen Roy and in Glen Collarig, there must have been a scooping away of the blockage. This is an important fact, because the blockage must have been of such a nature as to be capable of being lowered vertically, and of being scooped away horizontally.

We now come to the next subsidence of the lake in Glen Roy, as indicated by Shelf 4, which stands at a height of 856 feet above the sea.

This shelf goes up Glen Roy only for a certain distance, of course stopping at or near the part where the bottom of the valley rises to a level higher than

* It may be proper to explain that the lake did not subside at once 81 feet. Two intermediate shelves are visible between Shelves 2 and 3, in Glen Glaster (east side), in Glen Collarig, in Glen Roy on the south side above Aehavaddy, and on Ben Erin—*i.e.*, the hill above the Gap. One of these is about 14 feet below Shelf 2, the other about 32 feet above Shelf 3. So also, when the lake subsided from shelf 3 to shelf 4, there was a halt long enough to allow an intermediate shelf to be formed at a height of 990 feet, which is very conspicuous in Glen Collarig. None of these intermediate shelves are marked on the Ordnance Maps; they were, however, pointed out by me to the Surveyors.

856 feet. This time the lake sank so low, that it could not enter the lateral valley of Glen Collarig through the gap. But what is very important, the lake entered Glen Collarig at its south or lower end, and its beach mark is distinct on both sides of that Glen up to near the middle of it, as is shown on the map.

Some blockage of a permanent character must therefore have existed about this part of Glen Collarig, to prevent the two highest shelves, Nos. 2 and 3, going farther south, and also to prevent the lowest shelf, No. 4, going further north than the points where these shelves respectively stop. To this important discovery I will afterwards advert more particularly.

This lower shelf, No. 4, in Glen Spean runs a certain distance west, towards the glen occupied by the Caledonian Canal. It also runs up the whole length of Glen Spean to the east end of Loch Laggan at Makkoul, where the lake, when at that level, discharged eastward by the Makkoul valley (now dry) into Strath Spey.

The blockage which caused the waters of the lake to stand at this level, and forced them to flow out at its east end, must have extended across the country, between a spur of Ben Nevis and Teandrish, a distance, as the crow flies, of about 4 or 5 miles. This district, called Unichan, lying between Fort-William and Spean Bridge, consists now of tolerably flat ground composed mostly on its surface, of gravel, clay and sand.

The Author's Theory.

2. The view which I support is, that the lakes at all these different levels were kept in by an accumulation of detritus, which being from time to time lowered in level, caused the subsidence of the lakes, and being scooped away, allowed of the extension of the lakes, beyond the original blockage, to lower parts of the glens.

Mr DARWIN and others represent the impossibility of having barriers several hundred feet in height, and more than a mile long, composed of such loose materials as gravel or clay.

The objection would be well founded, if it was necessary to suppose that the lakes were kept in by barriers resembling *Dam-dykes*, which is the representation given of the blockage by some writers. This, however, is not a correct representation of the nature of the blockage suggested.

It is manifest that all this district of the Highlands was formerly covered by detritus, up to the height of at least 2000 feet above the present level of the sea; and that this detritus filled the valleys, including even the Great Glen which stretches from Fort-William to Inverness. I assume that the detritus had been deposited and spread over the country, when this part of Europe was submerged beneath the sea.

When the sea began to fall in level, so as to expose the land to the agencies of rain, snow, and frost, water would collect wherever there were depressions in the surface of the country, and form lakes. As the sea retired, the streams issuing from these lakes would acquire more power to cut out for themselves deeper channels where the materials were susceptible of erosion.

3. In support of this view, that the whole of this part of Scotland was covered with detritus, the following list of places, with their heights above the sea, is submitted :—

(1.) On the hills which surround *Glen Gluoy*, at a height of 1700 and 2000 feet above the sea, beds of sand and gravel 10 and 12 feet thick at least, are conspicuous in every lateral ravine, and in many of these ravines, the beds of sand and gravel form cliffs or scours nearly a hundred feet deep. These beds of detritus abound on *Letter Finlay Hill*, situated between the Great Glen and Glen Gluoy.

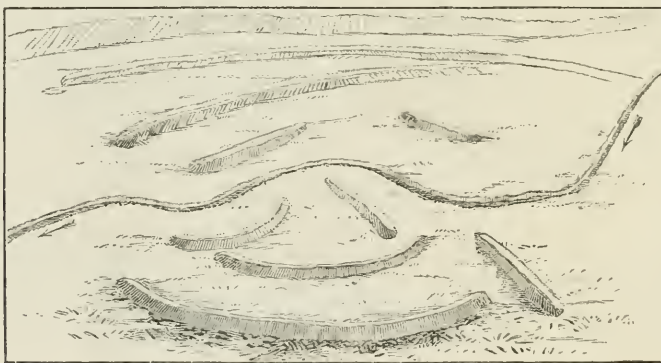


Fig. 2.

Portion of the wide valley of *Alt-na-Bruach*, showing some of the numerous Escars or Kaims occurring in it. These Kaims consist of gravel and sand, and reach heights of from 30 to 50 feet above the adjoining plain.

(2.) Near the summit of *Craig Dhu*, the hill between Glen Roy and Glen Spean, I found water-worn gravel at a height of 2000 feet above the sea.

(3.) On *Ben Chlìnaig*, a hill on the south side of Glen Spean, and nearly opposite to *Craig Dhu*, at a height of 1700 feet above the sea, beds of boulder clay and gravel are cut through by all the streams flowing down its sides. The beds are rudely stratified, and slope towards the valley.

(4.) In "*Alt-na-Bruach*,"* there are extensive Scours or Kaims of gravel and sand, up to a height of more than 1200 feet. Through these deposits the

* I am told that this Gaelic word means "Valley of high heaps or banks."

burns have cut deep ravines, whose banks consist of cliffs or scaurs, at least 400 feet high. Fig. 2 gives a representation of this *Alt-na-Bruach* Valley, as seen from the hill called Ben Chlainaig to the north. Fig 3. gives a section of one of the Escars.

(5.) On the hill situated to the N.E. of the "*Rough Burn*," situated on the east side of Glen Spean Valley, there are knolls of gravel at a height of 1700 feet above the sea. These knolls are the remaining portions of extensive sheets of drift, which have been washed away by rains and streams.

(6.) On the west side of *Loch Luggan*, I found abundance of coarse water-worn gravel upon the "*Bein-in hills*," as far up as I ascended, viz., 1890 feet above the sea.

(7.) In *Glen Collarig*, there is in a lateral valley on the N.E. side, an enormous cliff of grey boulder clay. It is full of boulders and pebbles, and forms a vertical wall from 300 to 400 feet in height, above the highest shelf.*

(8.) To the East of *Loch Treig*, at a height exceeding 1500 feet above the

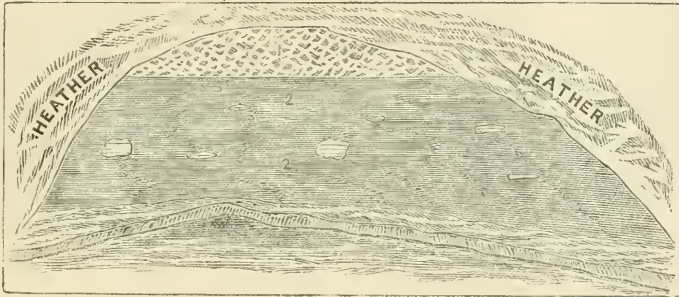


Fig. 3.

Section of an Escar in Alt-na-Bruach Valley, cut through by a stream. No. 1 is a bed of stratified gravel, about 6 feet thick. No. 2 is stratified sand, about 20 feet thick, containing boulders.

sea, a remarkable series of Kaims or Escars occur, consisting of detritus and Boulders.

In corroboration of these observations regarding the enormous accumulation of detritus in these Lochaber valleys, it may be permitted to refer to the testimony of preceding inquirers.

MACCULLOCH, whose precision of description is well known (page 327) describes the *hills* forming Glen Roy as "*covered with a thick alluvium*." The nature of this alluvium he explains as consisting "of deposits of fine sand, gravel, clay, and rolled stones of different sizes, disposed in a manner irregularly stratified, and in a manner more or less horizontal," (page 330).

DARWIN in his paper repeatedly alludes to the "enormous accumulation of

* To this cliff I particularly drew the attention of the Government Surveyors, and of Mr Jolly.

perfectly rounded shingle" in all the valleys. "These irregularly stratified beds, near the mouth of the Spean, attain a thickness of several hundred feet, and consist of sand and pebbles." Mr Darwin founds specially on the existence of these deposits at the *cols* of Gluoy and Roy,—1180 feet above the sea,—in support of his theory that the shelves were sea-beaches (page 43, 53, 65).

CHAMBERS, in his "Ancient Sea Margins" (page 123), referring first to Glen Roy, says "The bottom of the valley is *filled, to a great height*, with these alluvial masses, insomuch as to have appeared to some as in no small degree diminishing the difficulty as to barriers in that glen." Next, referring to Glen Spean, he says, "we find huge protuberances of detrital matter, starting out from the hills, and generally assuming a rude terrace-like form at 534, 627, and 734 feet above the sea."

CHAMBERS refers also to what he calls "the grandest delta of the district," called Unichan, occupying the lower part of Glen Spean. He describes it as "a mass of gravel, 11 miles long, by perhaps 2 broad, and reaching an elevation of 612 feet above the sea" (page 106).

Professor NICOL of Aberdeen (who like CHAMBERS adopts the sea-beach theory), referring to the "col" between Glen Roy and the Spey, at a height of 1150 feet above the sea, alludes to a line of stones left there, where the water had washed away the detritus. "From a lateral corry below Loch Spey,* *great masses of detritus* (he says) project into the main valley. These have been spread out and levelled down, as if thrown into the sea, not as if heaped up in a river valley" ("Proceedings of Geol. Socy. of London," 12th May 1869, p. 285).

He expresses an unhesitating opinion—

"That before the formation of the Glen Roy lines, *the whole region has been submerged in the sea*. This is proved by the uniform coat of detritus covering *the whole surface* in a thicker or thinner sheet, according to the form of the ground. This coat is not the surface waste, but *matter laid down by water*;—it is too wide spread and general in its distribution, and too much mixed in its composition, to have been formed in any mere lake." "It is *in this detrital cover* that the *lines* (meaning the Parallel Roads) are cut" (page 283).

JAMIESON, who adopts the theory of ice barriers, as suggested by AGASSIZ, takes special notice in all his papers of the extraordinary amount of detrital matter in the glens, and allows that there is more in *these* glens than in other Highland glens. In his paper (of 21st January 1863, "London Geol. Society Journal"), he says:—

"*Glen Roy* presents an *exceptional* character to our other mountain glens, not only in respect of its Parallel Roads, but also *on account of its great beds of silt and gravel*, and still more the wonderfully fine deltas at the mouth of its lateral ravines. All these local peculiarities—the lines, the deltas, and *the heavy banks of silt and gravel*, bespeak a *local* cause, such as a fresh water lake, and not a universally present one like the sea" ("Geol. Socy. Pro.," 21st January 1863, page 244).

* Loch Spey is about 1200 feet above the sea.

The foregoing localities for detritus are chiefly at places considerably above the level of the shelves, so that at the required levels, there were materials in abundance suitable to form blockages.

In the bottoms of the valleys, the accumulations of drift are of course much greater than near the tops or ridges of the hills. Scours or cliffs of detritus, in some places 80 feet high, are in all the ravines on the sides of the adjoining hills. On the Laire Burn (to the west of Loch Treig) there are scours of coarse clay and gravel nearly 300 feet high.

But is it likely that the detritus was deposited only on the tops or ridges of the hills, and in the bottoms of the valleys, and not also in what are now the hollows between the hills? Is it not quite as likely that the detritus, originally filled or occupied these hollows, so that originally no valley existed, at all events valleys of the depth which now exist?

Mr DARWIN argues (page 53), "that the *Valley* was once partly or entirely filled up, to the height of the shelves, by drift materials." To a certain extent I concur in this opinion. I think that the more the valleys were filled, the better we can understand how the very tops of the hills, as well as their sides, should have been covered, and should be still covered, by gravel and sand.

On these grounds, I submit, that in the Lochaber district, ample materials existed for forming detrital blockages of the Glens, to keep in and keep up the lakes to the heights which their shelves indicate.

4. When the land began to rise up out of the ocean, so that extensive portions of country became exposed, what would happen? That lakes would be formed at high levels, and be kept at these levels by detritus, is consistent alike with reason and fact.

There are even yet in this district of the Highlands, numerous lakes at high levels, kept in by detrital matter. Last October I visited Loch Earba, a lake about 4 miles in length, situated about 2 miles to the South of Loch Laggan. That lake is at a height of about 1120 feet above the sea, and is kept up by a mass of detritus, through which the stream from the lake has cut its way to Loch Laggan. There happens to be a quarry or pit near the point of discharge, for getting from it gravel and boulders, to be broken into road metal, which shews the character and thickness of the detritus at this place. The waters of Loch Earba, however, formerly stood higher than at present, as is shown by a horizontal beach line about 30 feet above the present level of the lake, which runs for several hundred yards at its north end along its west bank. This beach line is traceable also near the south end.

In the same district of Lochaber, there are other two or three lakes at even greater heights, which I was informed, though I have not visited them, are in like manner kept up by detritus.

There are numerous lakes at lower levels, also kept in by detrital

accumulations. Loch Laggan, Loch Treig,* Loch Lochy, and Loch Arkaig are examples. Arkaig is specially interesting, because there is evidence to shew, that at some former period it discharged into Loch Lochy by a channel different from the present one. The old channel is situated at the N. E. end of the lake, and forms a deep dry ravine, called "the Dark Mile." The present channel of discharge is at the S. E. corner. Near the mouth of the lake there is a horizontal terrace, about 90 feet above the present surface, formed on detritus, which suggests that the lake once stood at a higher level.

Loch Laggan now discharges its surplus waters by the River Spean, which has cut for itself a trench about from 30 to 40 feet below what had been here the bottom of the lake. One side of the trench is shown on fig. 4. It

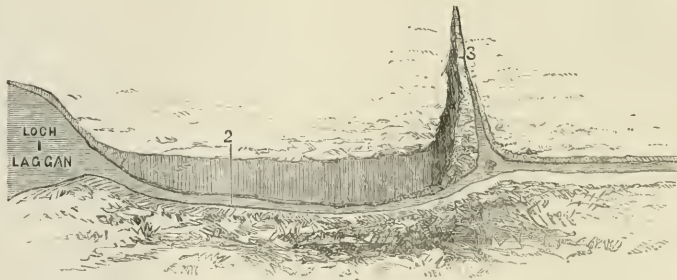


Fig. 4.

Loch Laggan (1) now discharging its surplus waters by the River Spean (2). About a quarter of a mile below the Loch, the Spean is joined by the River Gulbain (3). Both rivers have cut deep trenches through the old bottom of the Lake, viz., the lake which formed Shelf 4.

forms a cliff running for several hundred yards towards the west, till it joins another cliff almost at right angles, which has been formed by the River Gulbain. The material cut through by both rivers consists of sand, and fine clay in horizontal beds, formerly the bottom of the lake which formed Shelf 4. The trench cut by the river would have been deeper, but for rock over which the Spean flows where it runs out of the lake.

In my former paper, I referred to a case somewhat analogous, where a lake had subsided from one level to another, and which is kept up at its present level by detritus. This lake is Loch Tulla, about 3 miles long and 1 mile broad, situated about 40 miles S. W. of Glen Roy. CHAMBERS, after I had pointed out this lake, as a case supporting my theory, visited it, and in his book on Sea Margins admitted the correctness of my statements, as to the horizontality

* Mr JAMIESON (page 250, "London Geo. Soc. Pro.," 21st January 1863), admits Loch Treig, in its outflow, "has not even yet cut its way to the very bottom, for the lake is *still partly retained by banks of gravel.*"

of the several shelves encompassing the lake, and their distance from one another. The surface of the lake is (approximately) 630 feet above the sea. But originally its waters had stood at a height of 1132 feet above the sea; and my position was, that the barrier which kept it in consisted of detritus which from time to time was eroded by the river discharging from the lake. I also stated that there existed still, at and near the point of discharge, "*great heaps of unstratified gravel,*" which form the present blockage. This statement Dr CHAMBERS did not question. Nevertheless, he adhered to his opinion, that the shelves round the lake, "*may all have been produced by the sea*" (page 129).*

Another case of the same kind occurs near Kingussie. Loch Gwynac is about a mile in length and 300 yards wide. The present level of the loch is (by Ordnance Survey) 1015 feet above the sea. There are five horizontal terraces, traceable at the following heights above the lake, viz.:—26 feet, 44 feet, 52 feet, 96 feet, and 132 feet. These terraces have been formed on the drift, which here as elsewhere in the Northern Highlands overspreads the whole country. The blockage which kept the waters of the loch up to the heights of these terraces has disappeared, so that there must have been enormous denudation and scouring out of the drift in this valley.

The flat district north of Dunkeld, where the Dalguise and Balingluig Railway Stations are situated, was formerly a lake. The old Beach line, about 60 feet above the present level of the River Tay, is tolerably distinct. The blockage consisted of a mass of detritus, which was worn down and cut through by the river. A considerable portion of this blockage still subsists, forming a huge embankment transverse to the valley.

Two years ago, when at Inverie, on the west coast of Argyleshire, Mr BAIRD, whom I was visiting, took me to a place a few miles north on the same coast, called Invergussern. There I found a flat valley with a stream (the Gussern) meandering through it. On each side of the valley there are hills, along the base of which a beach line about 50 feet above the present surface was manifest. When I came near to the sea-shore, I found a great ridge of sand and gravel crossing the mouth of the valley, and which, as it impinged on the hills on each side, could, so long as continuous, have effectually kept up the waters in the valley to form a lake. Figures 5 and 6 will assist to make this description intelligible.

The River Gussern had evidently cut through the bank S S, and also a portion of the slate rocks beneath, and so allowed the lake to be drained.

* A few years ago, when at Killin, at the west end of Loch Tay, I made some ascents of the hills adjoining, and saw traces of several lines of terrace up to a height of 890 feet above the lake, and 1240 feet above the sea. Along the north side of the lake there is an extensive flat at a height of about 400 feet, which seemed to have its counterpart along the south side of the lake. I mention this only as a suggestion for farther inquiry. I believe that the late Mr M'LAREN described some terraces at the east end of the lake, about 40 feet above it, but I have not his papers to refer to.

The top of the barrier I found to be about 90 feet above the level of the river, and 135 feet above the sea. The bank of sand is about 35 feet deep and 100 yards wide, the depth of the erosion of the rocks is 50 feet.

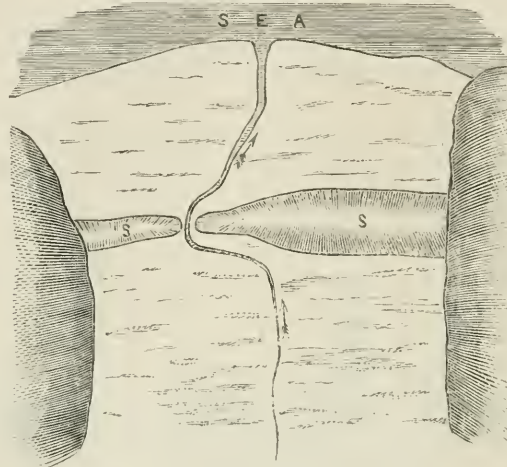


Fig. 5. (See p. 607.)

Ground Plan of detrital bank near the mouth of the River Gussern, crossing the valley. SS represent the two portions of the bank still remaining, and united to the hills on each side.

Glen Spean Valley represents several examples of the same kind. Near the falls of Monessie, detritus had originally filled the valley to such a height as to form a lake, the surface of which reached a height of 520 feet above the sea. The beach line of this lake is distinctly traceable from Auchenleuirich Post



Fig. 6. (See p. 607.)

Section of detrital bank in valley of Gussern, showing how the river has cut through it, and the subjacent rocks.

Office and Monessie at its lower or West end, to Inverlair Falls at its upper or East end, a distance of about 3 miles. Figures 7 and 8 are intended to shew how the lake was drained. At Monessie, the channel of the river is about 100 feet below the level of the old beach line. A great mass of detritus still crosses the valley here for about two-thirds of its breadth. The river issuing from the lake, cut through the detritus, and drained the lake.

From the foregoing statements, two points seem established.—(1.) That all

over this district of the Highlands, detritus formerly existed to such an extent, that blockages might have been formed by it, to keep up lakes existing in the

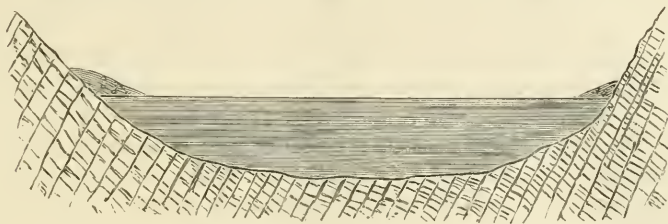


Fig. 7. (See p. 608.)

Section showing lake supposed to have formerly existed near Monessie.

country to the requisite height ; and (2.) That there are many cases now in the Highlands, of lakes kept up in this manner ; (3.) That lakes have subsided, and even drained altogether, by the wearing down and removal of detrital blockages through the action of rivers.

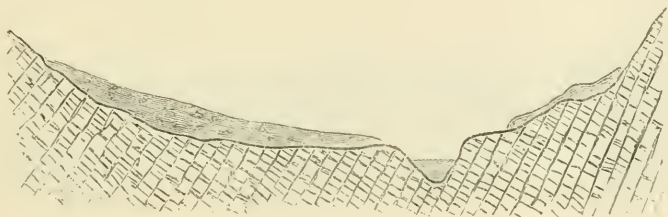


Fig. 8. (See p. 608.)

Section showing the same spot near Monessie after the lake was drained, by the River Spean having cut through the detritus and subjacent rocks.

5. If these views be applied to the Parallel Roads in the respective glens, they will be found sufficient to explain by what means these Roads stopped at the places marked on the map.

(1.) As the two shelves of Glen Gluoy appear only in the upper part of the glen, some blockage must have existed at its mouth. I shall revert to this Glen Gluoy blockage in a subsequent part of the paper when discussing the blockage of the Great Glen. Meanwhile, I would refer to a peculiarity in Glen Gluoy, that the upper shelf extends farther down the glen than the lower shelf. A B in fig. 9 is the hill forming one side of the valley on which the shelves are marked, C C is the highest shelf, and D D the lowest. The greater extension of the upper shelf may be accounted for, by supposing that the detrital blockage E, sloped in the way shown in the figure, which is the usual form of a lake bottom.

(2.) It is not difficult to understand how or why the blockage changed position and level, *if it was detritus*. There are, in all the Glens, multitudes of

streams which now flow down the sides of the hills. These streams must have existed during the period of the lakes. They may have flowed not only into the lake, but also upon the detritus near the lake in Glen Roy at its south end, and have cut out channels through the detritus, which filled that Glen near the present mouth of Glen Glaster. The distance between the highest blockage in Glen Roy (viz. for Shelf 2) and Glen Glaster was small, probably not more than a few hundred yards. The intervening mass of detritus would, by the action of the hill streams, after a time be worn down, and then the outflow of the lake would take the course of Glen Glaster, leaving untouched the remainder of the detritus between Craig Dhu and Bohuntine.

If this was what happened, it is natural that the new line of blockage should be (as shown by the terminations of Shelf 3) right across Glen Roy, and parallel with the new outlet through Glen Glaster.

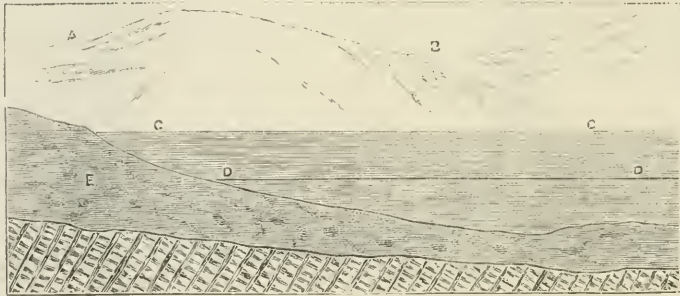


Fig. 9. (See p. 609.)

Section to explain why the upper shelf in Glen Gluoy C C extends farther down the glen than the lower shelf D D.

It is important next to notice what happened in Glen Collarig. It will be seen from the maps (Plates XXI. and XLII.) that Shelf 3, when the lake subsided to it, made its mark along the west side of Bohuntine Hill, and also on the opposite hill. The scooping out of the Collarig blockage need not have happened at exactly the same time as the change in the Glen Roy blockage. But the change was of the same nature, and was probably produced by a similar cause. Strong streams rush down on each side of Glen Collarig, and at or near the very place where the blockage must have originally existed. These streams, descending on the detritus, would wear down and remove a large part of it, and so allow of the extension of this arm of the lake farther south in the glen.

The next change which took place was the entire removal of the blockage between Craig Dhu and Bohuntine, whereby the lake reached the lowest level, viz., that marked by Shelf 4. This change might be effected in the course of the general erosion which had long been going on. In the first place,

there was a strong stream or river flowing through Glen Glaster from the lakes occupying Glen Roy and Glen Gluoy. Then there were streams descending from the Glen Roy hills on both sides. On the south side there was the Bohina Burn, and on the north side the river from Glen Collarig. These numerous streams would act on and annihilate the blockage which kept up the Glen Roy Lake to the middle shelf. The result would be an entrance of lake 4 into Glen Collarig by its south end; and accordingly it will be seen from the map, (Plate XLII.) that Shelf 4 goes up Glen Collarig, but stops on both sides at a point which is *only a few hundred yards from the place where the middle shelf came to, from the north*. What was it which prevented Shelf 4 reaching further north?

The ground plan on Plate XLII., taken from the Ordnance Survey, shows where this blockage must have been situated. It must have been between the points where Shelves 2 and 3 terminate, and the points where Shelf 4 terminates.

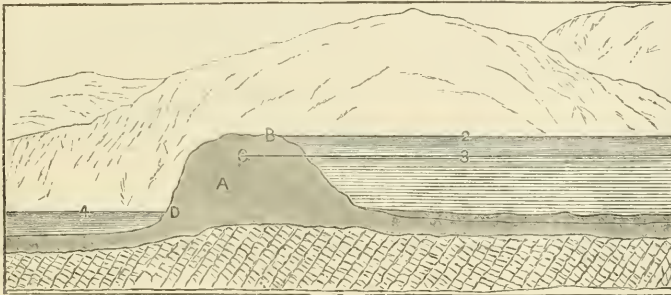


Fig. 10.

Section showing in Glen Collarig the termination of Shelves 2 and 3, viz., at B and C, and of Shelf 4 in a lower part of the glen, viz., at D, with the supposed detrital blockage A which separated the lakes.

The intervening space must evidently have been occupied by a blockage (A in fig. 10), which answered the double purpose of keeping separate the waters of Shelves 2 and 3 (viz., B C), and the waters of Shelf 4 (D). This intervening space, when measured on the ordnance map, gives an average thickness of blockage or barrier of about 660 yards. The width of the blockage (crossing the glen) need not have been more than 800 yards; and the depth of the blockage, for the highest of the shelves B, even supposing that the glen was as deep then as now, would not have been more than 368 feet. But making allowance for the erosion of the valley, since the time of the Parallel Roads, the probability is that a blockage of considerably less height was sufficient, and existed.

The detrital mass A (fig. 10), at first must have been in such quantity as to reach northwards to where the highest shelf, No. 2, stops, viz., B. It then was scooped out or was undermined on that side for 50 or 60 yards, so that when

the lake fell to Shelf 3, the waters in Glen Collarig reached to C in fig. 10, and thereafter, on the removal of the blockage between Craig Dhu and Bohuntine, the waters of the lowest shelf came up Glen Collarig to the place (viz., D), where the detrital blockage above referred to existed.

When the lake sank to the lowest shelf* (No. 4) in the glens, by the removal of the blockage between Bohina and Bohuntine, the waters of the lake occupied the whole valley of the Spean. Shelf 4 is traceable as far as the east end of Loch Laggan; and towards the west to Teindrish on the one side and Corry Cholzie and Corry N'Eoin on the other side.

And what was the blockage at this point? The intervening space between the two shelves at this their Western termination is no less than five miles in length. Could there have been a detrital barrier here also? There are good grounds for believing that there was. The whole of this district, as Dr CHAMBERS explains, consists of "*a mass of gravel 11 miles long by perhaps 2 broad, and reaching an elevation of 612 feet above the sea.*" I have traversed the district in many directions, and can attest that it presents an enormous accumulation of drift deposits,—not gravel only, but also of sand and clay;—at one spot only does rock come to the surface. Streams cut through this extensive drift plateau from the Aonachmore hills, situated to the south. There are no less than five mountain torrents in the course of two miles in this part of the district. These streams present deep gashes through the detritus, and when they reach the base of the hilly range, unite into considerable rivers, which run, some north to join the Spean, others west towards Fort-William. The scouring out of detritus along the base of these hills has been very great. The result has been a valley deep and wide in an east and west direction. In company with the Rev. Mr CAMERON, minister of the parish, I walked along this valley towards Fort-William. Part of it consists of an elongated marsh, formerly a lake, whose margin had been about 20 feet above the marsh, the surrounding cliffs being detritus. Farther west I came upon a small lake, the banks of which, composed of detritus, are about 170 feet high, showing on their sides two or three terraces, proofs that either the lake had subsided from one level to another, or that the river had eroded first on one side and then on another at the above levels before reaching its present channel. The river has now reached rock, so that further subsidence is arrested.

In different parts of this lower district, knolls and banks of detritus stand up above the general level. It would therefore require no great amount of restoration to supply a detrital blockage sufficient for damming the great lake indicated by the lowest Glen Roy shelf, which is 854 feet above the sea.

* I have already explained, that the subsidence of the lake from Shelf 3 to 4 did not take place all at once. It sank at first only about 78 feet, and formed an intermediate road visible in Glen Collarig, at its north end, on both sides.

When the sides of the hills are examined, on both sides of the valley where this lower shelf terminates, abundance of detrital matter is still traceable. At Teindrish, which is on the north side, there are great cliffs of tenacious clay, full of boulders, reaching to a height of at least 1000 feet above the sea. Similar deposits, and at as high a level, exist on the south side of the valley, viz., at Corry Choilzie and Corry N'Eoin.

But there are other conditions which suggest even a higher and more extensive blockage in this quarter. The Glen Gluoy shelves imply a blockage reaching to a height of 1170 feet above the sea. How long did this Gluoy lake continue even at its lower shelf, which is about 970 feet above the sea? Glen Gluoy opens its mouth on the Great Glen; and the highest shelf in it reaches to a point within a mile of Loch Lochey. The probability therefore is, that if

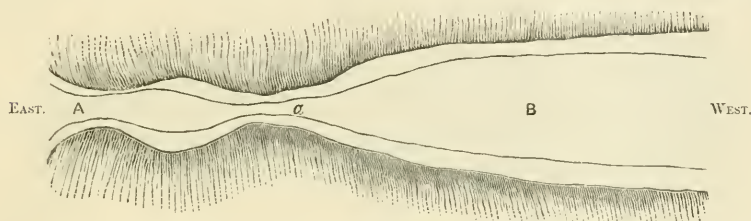


Fig. 11.

Ground plan to show the position of the Kilfinnin shelf, first discovered by Mr Darwin. B is the valley to which Mr Darwin supposed the shelf to be confined, terminating at the summit of the valley a . But the shelf passes eastward into the adjoining valley called Glen Buck, marked A.

detritus blocked the Glen Gluoy Lake, this detritus formed part of an accumulation which filled the Great Glen in this part of its course.

Then there is the shelf at the place called by Mr DARWIN, *Kilfinnin*, at a height of about 1300 feet above the sea. "Mr DARWIN states that, having observed this shelf from many points of view, he is prepared positively to assert that it is in every respect as characteristic as any in Glen Roy; and that its origin must be as carefully attended to in any general theory of the formation of the shelves" (p. 45). In company with the Rev. Mr CAMERON, who is probably more than any one familiar with the character of the Glen Roy Parallel Roads, I twice examined this Kilfinnin shelf. It is in a high valley on the south side of the Caledonian Canal, opposite to Invergarry. The valley is called Laggan, and is roughly represented in fig. 11. It runs parallel with the Great Valley. The shelf is visible on both sides of Laggan Valley. But it does not terminate with the head of that valley at a , as Mr DARWIN seems, from his brief description of it, to have supposed. The shelf passes over the summit level or col which divides Laggan Valley from the valley to the east called Glen Buck, as shown in the diagram.

At the summit level between the two valleys, the hills on each side approach one another. The shelf there is only about 20 feet above the dividing summit ridge, and the space there, between the shelves is from 230 to 250 yards.

On the hills here, as elsewhere, there is a large amount of drift, consisting of huge deposits of sand and rounded gravel. I saw it up to the highest level of the hill reached by me, viz., 1516 feet above the sea.

The shelves in this valley, as elsewhere, have been formed on the detritus. This detritus therefore had come anterior to the formation of the shelf.

I agree with Mr DARWIN that this Kilfinnin shelf is of the same character as the Lochaber shelves. The width of the shelf is not nearly so great as those in Glen Roy. The smallness of the lake would account for this difference. It has another feature of importance, the same as the Glen Roy shelves. Its slope



Fig. 12.

Plan (not to any scale) of part of Loch Ness, to show where deposits of detritus now exist.

down from the hill-side towards the centre of the valley is exceedingly slight—indeed, hardly perceptible.

On this account I am inclined to think that this shelf was made, not by the sea, as Mr DARWIN thought, but by a lake. A sea beach, owing to the action of the tides and waves, never can be so horizontal as the beach of a small lake.

But if a lake, where was the blockage both for Glen Laggan and for Glen Buck ?

The most probable explanation seems to be, that *the Great Glen had here also, been filled by detritus up to a height exceeding 1300 feet.* Indeed, I cannot doubt that the whole of that great valley, from Fort William to Inverness, must have been, at the epoch now referred to, filled with detritus; and that the extensive gravel hills at the East end near Inverness (For Vane and Tomnahurich) are remnants of this detritus.

That this was really the case seems plain, from the numerous remnants of detritus which occur along both sides of the Caledonian Canal.

Fig. 12 represents a small portion of Loch Ness near Foyers. The parts marked 1, 2, 3, 4, 5,* represent accumulations of drift, which in some cases

* No. 1 is Ruiske. No. 2, Lein. No. 3, Urquhart. No. 4, Foyers. No. 5, Inverfarrigaig.

have a depth or thickness of hundreds of feet. These accumulations occur, wherever the range of the hills retires from the general axis of the valley, to produce a bay and a depression of surface. These hollows have been and are still filled with drift. Assuming that the whole of the "Great Glen" was so filled; the drift has subsequently been scoured out by powerful agents passing through it, leaving untouched the drift where sheltered in side bays and depressions.

In the ravine of the Inverfarrigaig river (about three miles to the east of Foyers Hotel) there is a very interesting cliff of clay, rudely stratified horizontally, and full of well rounded pebbles and boulders, with thin horizontal seams of sand. The scaur extends for about 250 yards. It is about 50 feet in height. It is 120 feet above Loch Ness. I cannot doubt that this bed of drift has been part of the general accumulation which filled up the Great Glen.*

These deposits, so long as they filled the Great Glen, would facilitate, in the districts adjoining, the formation of lakes, and ensure the retention of these lakes at high levels, because the rivers discharging from them would at first have small power to cut through the detritus. But with the lowering of the ocean level, the removal of detritus everywhere would increase with the steeper gradients of the rivers, and with the greater area on which rain would fall. Nowhere would the removal of detritus be so rapid as in the Great Glen, owing to the height and steepness of the mountains on each side. The removal of detritus would probably be greater at the west end of the Glen than at the east end, because of the greater height of the mountains at the west, and a larger supply there of rain. The reason why portions of the detritus remain at the east end is, that the hills there are lower in height, and more apart from the central line of the great valley.

On these grounds I think that when lakes existed in Glens Gluoy and Roy at their respective heights, exceeding 1100 feet above the sea, there was detritus

* In all the valleys adjoining or near the "Great Glen," there are still enormous deposits of drift, much of which evidently has been removed by rivers. Thus, in a valley called Flichity (about 12 miles S. W. of Inverness) drift covers the hill sides up to the height of 2000 feet; and in that valley there are traces of horizontal terraces, on the sides of the valley, more than 100 feet above the bottom, with a blockage of drift, at the lower or east end of the valley, which before it was cut through by the River Nairn must have been the means of causing the valley to be filled with water.

At Rosemarkie, a few miles N.E. of Inverness, which Mr JOLLY of Inverness took me to visit, there are magnificent sections of boulder clay, forming cliffs about 300 feet high. If the adjoining hills are, as they seemed to be, from their shape, composed of the same material, this deposit reaches to a height above the sea of 800 or 900 feet. How far down below the sea-level this clay deposit goes, it is impossible to tell, but at Fort George on the opposite side of the Firth, about three miles distant, a bore was sunk 100 feet in the same sort of clay, without reaching the bottom. Here then a clay deposit exists about 1000 feet in thickness. Judging from the beds of sand in the clay, and from the pebbles in it being in nearly horizontal lines, I had no doubt that this Rosemarkie clay bed was a water deposit.

exceeding that level, occupying not only the Great Glen, but also the entire district of Unachan towards Fort William.

6. Having in the foregoing remarks explained my reasons for thinking that the whole of this part of the Highlands was covered by drift, the next point to which I would advert is the facility with which this detrital matter can be and has been removed by natural streams and rivers.

As an example, I may refer to a deep gully near the Old Catholic Burying Ground near Achleuerench in Glen Spean, called Cillochrill. It is situated on a flat bit of ground, part of the old lake bottom when the water stood at the lowest shelf. This ground consists of an immense mass of gravel, which presents, towards the turnpike road, steep banks of from 300 to 350 feet in height. My guide, ANGUS McMASTER, had been resident in the Glen since boyhood, and he pointed out to me the gully above referred to, which he stated had been formed within his own recollection. He said that it had originated from the plough having formed a "*furr*" on the flat land too near the edge of the bank. The rain scooped out a channel through the detritus and formed the gully. The banks of the gully are from 40 to 50 feet high, and the width in some places about 80 yards.

In Glen Roy there are numerous examples of burns having formed deep gashes through the original beds of clay, which had formed the bottoms of the old lakes. At the road on the east side of Bohuntine, which descends to Craunachan Bridge, there are vertical cliffs of clay, full of pebbles and boulders, 240 feet high, due to the erosion and undermining of the river Roy. It has even cut for itself a passage through the rocks lying beneath the boulder clay, in some places 60 to 80 feet in depth. This stream has enormous power.

Any one who walks along the banks of the River Spean from Spean Bridge to its mouth in Loch Lochy, will not fail to be struck by the height of the detrital cliffs lining its course.

The river channel is in some places at least 300 feet below the adjoining general surface, and there are terraces corresponding with the successive subsidences. The diagram, shown in fig. 13, is a view taken from the left bank of the River about a mile below Spean Bridge. The old Haugh-land next the river is about 35 feet above it, bounded by a detrital cliff about 20 feet high. Above this cliff there is a second haugh about 60 feet above the river, which is bounded by another detrital cliff about 20 feet high. As these banks and haughs slope with the river, there can be no doubt that it produced them. Even still, the old banks are so distinct as to show that the river Spean here ran along a channel more than 100 feet above its present level; so that the quantity of drift removed by it has been enormous.*

* Since this passage was written, I have again examined the Spean. The banks and cliffs referred to in the text, are situated on the east side of the river, about half a mile below Kilmonivaig church.

The *Spey* valley, from its summit at Lochan Spey down to Kingussie (beyond which I have not examined it), shows everywhere similar deposits of drift and similar denudation. Though I did not reach a higher level in my survey than 1161 feet above the sea, I saw that the ^{at} was detritus on the hill sides at

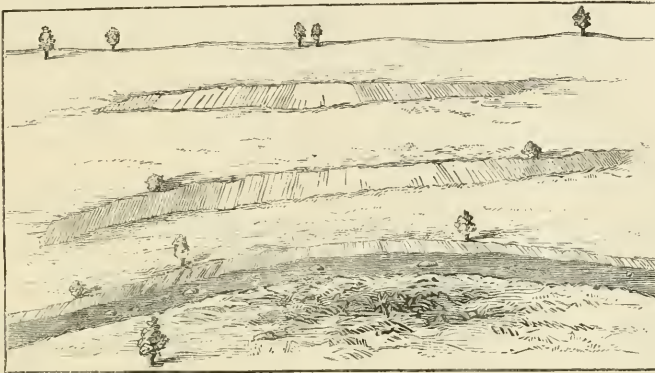


Fig. 13. (See p. 616.)

River Spean, with old River Cliffs and Haughs, viewed from the left bank at a point 100 feet above the stream.

least 200 feet higher. The power of a river and its tributaries in scouring out a wide district of its detrital covering is well shown in this valley. All along the course of the *Spey*, there are numerous cliffs, at some distance from the river and approximately parallel with it, indicating the high levels at which the river formerly ran, and the large amount of materials removed by it. At Garve Bridge, 977 feet above the sea, a tributary called the "*Oig*" joins the *Spey*. On the right bank of this tributary there are 3 or 4 terraces one above another (to a height of about 120 feet above the stream), being the different levels at which it has successively run.

At "*Guthbeg*" near *Laggan Church* in *Strathspey*, cliffs of detritus face the river, reaching to about 324 feet above it. Banks and terraces on each side of the river continue down to Kingussie.

These terraces show that at a former period the River *Spey* in its course between *Laggan Church* and *Kingussie*, had formerly flowed at least 200 feet higher than now, and must have scoured out the wide valley, at the bottom of which the town of *Kingussie* stands.

There are similar banks on the west side of the river. I could not make out at this second visit, very clearly, whether the base of the banks sloped with the river or was horizontal. If horizontal, they would of course indicate a lake, with a river running through it. In a higher part of the river, viz., above the Roman Catholic Chapel, there are old river cliffs, which show that the river had formerly ran 180 feet higher than it now runs at that place.

MR JAMIESON of Ellon ("Lond. Geo. Soc. Journal," Vol. xiv. p. 526) has described a series of terraces extending on both sides of the Spey, in a lower part of its course, viz., at Ballindalloch, Aberlour, Rothés, and Cairnty, over a distance of about 25 miles. These terraces slope down with, and therefore have been made by, the river. He measured their heights very exactly at Rothés, and found them to be there 247 feet above the river. He has described the materials composing part of one of these terraces at Rothés in a cliff, thus—

Loose Sand and Gravel stratified	30 feet.
Stratified Sand and Mud	47 "
Gravel and Sand stratified	15 "
Unstratified Pebbly Clay	15 "
Stratified Sand and Mud	35 "
Base of Bank descending to River	50 "
	192 feet.

MR JAMIESON has no hesitation in looking on these beds of detritus as having been deposited when the sea prevailed over the country. Since the retirement of the sea, they have been cut through by the river, so that the height of the cliff, at the foot of which the river runs, shows the enormous amount of detritus removed.

Keeping in view these proofs of the action of rivers in eroding and removing detritus, there should be little hesitation in allowing that the blockage of the Lochaber lakes may have yielded to the agencies of the streams which descended upon them from the high and steep hills surrounding the lakes.

7. Two objections have been taken to this theory of detrital blockage which it is right to notice.

(1) It is said by Mr Darwin, that if the subsidence of the lake in Glen Roy, from the highest level to the next, took place by the wearing down of any of the sides of the lake, this wearing down would be at the end of the lake where it was discharging its surplus waters, viz., at the head of Glen Roy; whereas the wearing down is supposed to have been at the opposite end of the lake. If Glen Roy was filled by a lake, which when it stood at the highest shelf, overflowed at its N.E. end into the valley of the Spey, it is contended that the erosion of a deeper channel for the overflow would be at that end where there was already a stream fit to effect the work.

This objection it is not difficult to answer. The erosion and lowering of the blockage would occur at that part of the lake banks where the materials composing these banks were most susceptible of erosion.

The *col* or summit ridge between Glen Roy and the Spey Valley being hard Granite *rock*, it was not so likely to be eroded, as the west end of the lake, if it consisted of detritus, which would be easily undermined, cut into, loosened and carried off by streams from the hill sides.

At the next level of the lake, viz., shelf 3, when its waters were discharging through Glen Glaster, there was also rock at that *col*. But if the blockage between Craig Dhu and Bohuntine for Shelf 3 was detritus, there would be no difficulty in the gradual erosion and ultimate removal of it, to allow another subsidence, viz., to Shelf 4.

What happened in Glen Roy, according to the view now submitted, is not without precedent. Lake Winnipeg, in North America, is about 300 miles long by 60 miles broad. It now overflows at its north end into Hudson's Bay, by the River Nelson. But from a recent survey it appears, that *it formerly discharged from its south end*, into the valley of the Mississippi.

This would be the case, if the waters of the lake stood about 360 feet above its present level, provided there was a *blockage* at the *north* end, reaching to that height above the lake. That the lake had stood at this higher level, is attested by the existence of four or five bluffs and terraces, on each side of the lake, one above another, up to a height of 360 feet above its present level. Some of these terraces run for long distances,—one for no less than 120 miles, forming “*a continuous and horizontal gravel road beautifully arched, about 100 feet broad.*”

These may in fact be called the Parallel Roads of Lake Winnipeg. The valley of the Minnesota, through which the lake at a former period discharged southwards, affords by its elevated and continuous bluffs on each side, unmistakable proof that a river, very much larger in size than the stream occupying that valley now, did flow through it from the north. The whole of this region of North America is covered by drift to a great extent and depth. Every lake in it is surrounded by beaches at high levels, all formed on drift deposits. But the peculiarity of Lake Winnipeg is, that whilst it stood at its higher level, it certainly overflowed at its south end, and as it sunk to its present level (which it accomplished by successive stages), it changed its overflow to the north end. Major WARREN, the most recent surveyor of the district, states, after an examination of the River Nelson by which the lake now discharges into Hudson's Bay, that this river “has every indication of being of recent origin,” for reasons which he specifies. He adds that “the first material of the bed of the new outlet was probably *loose drift*, so that it was easily removed, and the outlet widened and deepened.” From Major WARREN's report, it rather appears that the summit level between Winnipeg and the Minnesota is a ridge of *granite*,—another feature in which it resembles Glens Roy, Gluoy, and Glaster. He adverts to an opinion suggested by some geologists, that a glacier may have moved over the country from the Arctic regions to the lake on the north side, and compelled an overflow towards the south. But this theory he makes short work of, terming it “an unsupported hypothesis, and barren of

any fruit." ("Essay on the Physical Features of the Valley of the Minnesota," 1874. See also "American Journal of Science" for 1875, p. 313.)

2. Another remark to the disadvantage of the detrital theory is, that if there was any blockage of that nature, some remains of it should still be extant.

Dr CHAMBERS says,—

"If the termination of any of the lines were the proper index to the termination of any of these alluvially confined lakes, we should expect to see some remnants of the blocking matter left at those places, say as hummocks on the sides of the vales with only broken passages between. But the lines vanish gradually on the smooth hill-sides, without any particular mark to distinguish the spots." (See "Margins," p. 113.)

This objection, at the best, is one only of probability. The argument is, that if there was any detrital blockage, fragments of it, in the forms of hummocks, might have been expected to be preserved. But there was little reason to expect, looking to the nature of the "blocking matter," that any of it would be preserved. When this "blocking matter" was undermined, scooped out, and washed away by streams, the probability is that the whole would be removed.

ROBERT CHAMBERS admits that in front of Bohina village (p. 123) "the bottom of the valley is filled to a great height with alluvial masses, which appear to some as diminishing the difficulty as to barriers."

I examined particularly the two places in Glen Roy where the blockages are supposed to have existed on the lake theory.

At the part of Glen Roy, where the highest shelf stops, there it is that the narrowest part of the valley occurs, and it is therefore a spot favourable for a blockage. On Bohuntine hill there is at that spot (I quote from my Notes) "a cliff of drift which runs down the hill *transversally to the valley*, and may have been a remnant of the barrier which crossed the valley here." On the south side of the Glen, immediately opposite to the above point, there are "some detrital mounds on the hill side about 1022 feet above the sea, which may have formed part of the same barrier." (Notes, vol. i., p. 23.)

Then at the place further west in Glen Roy "on the north side, where Shelf 3 terminates, there is a large mass of detritus *standing out transversely to Glen*." (Notes, vol. ii. p. 34.)

I give these quotations from my Notes, to show that there is not, as CHAMBERS and DARWIN state, a total absence of all appearance of detrital matter from the hill sides where the shelves stop. When first I saw these long mounds of drift I looked upon them as remnants of the blockage. But they may be only part of the lake bottom cut up by streams from the hill sides.

It is proper here to advert to the parts of Glen Roy, probably reached by the lakes at its two first subsidences.

It has been assumed hitherto that the uppermost lake at 1149 feet above the sea did not extend further west than Cranachan, because the highest shelf is

represented on the maps as stopping there. But on the occasion of my last visit to Glen Roy, Mr JOLLY and I thought we saw traces of the highest shelf on the north-west corner of Craig Dhu, which forms the south side of Glen Glaster.

If this discovery is confirmed, there need have been no blockage at Cranachan. The blockage must have been at two other places,—viz., first across Glen Glaster, and secondly across Glen Roy, between Bohuntine and Craig Dhu.

A blockage in Glen Glaster would be very easily accomplished, as the width there at the summit level is only one-fourth of the width of Glen Roy at Cranachan, and the lake there might not have been deeper than 81 feet. A very small barrier would be sufficient at that point.

A barrier across Glen Roy between Bohuntine and Craig Dhu would require no change when the lake subsided from Shelf 2 to Shelf 3, so that in that aspect of the case, the blockage is attended with few difficulties.

The objection to the detrital theory which has been most strongly urged, viz., the great height of the required barriers, assumes that *Glenroy and all the valleys of the district had then the same width and the same depth as now*. But if the valleys were still occupied by a large proportion of the detritus which originally filled them, that objection is entirely obviated.

When these Lochaber lakes existed, the sea may still have been from 500 to 600 feet higher than at present. There are in the district, between Fort William and Spean Bridge, a number of remarkable Escars and Flats, at various heights up to even 500 feet, which strongly suggest the prevalence of the sea. There are in like manner extensive plains to the south of Inverness, at about the same level, which have been apparently sea-bottoms. Even in the Great Glen itself, there are on its sides horizontal water-lines at various heights referable to the sea. Now, if when the Glen Roy lakes existed, the sea stood from 500 to 600 feet higher than at present, all the rivers in the country must have been running in channels much higher; and, therefore, at that time the valleys could not have been so deep or wide as they now are.

It is therefore a mistake to assume, that because Shelves 2 and 3 in Glen Roy are about 700 or 800 feet above the bottom of the valley, this affords any indication of what had been the depth of the valley when the lake existed, or of the height of the required barriers. The probability is, that the Glen Roy lake was not 100 feet deep.

Another remark of some weight arises out of this higher level of the sea. If, when the Glen Spean lake existed, having a height of 856 feet above the present level of the sea, the sea was then 600 or even only 400 feet above its present level, the sea must have been close to the detritus which I suppose to have formed a blockage of the lake between Teindrish and Aonach More. This

blockage would thus be subject to the eroding action of the sea, as well as to that of streams issuing from the adjoining hills.

IV. Having in the foregoing part of this memoir explained my own theory, and noticed some of the objections to it, I refer next to the other solutions of the problem which have been suggested.

Darwin's Marine Theory.

1. From what I have said regarding the prevalence of the sea over the highland hills, and the deposit of detritus, by means of sea currents, it might be supposed that I could scarcely refuse assent to Mr DARWIN'S views. But whilst I admit that there are traces of the sea at great heights on our coasts and mountains, it is not inconsistent to hold that whilst the sea was subsiding, lakes would be formed in favourable districts.

In the first place, let me state the grounds on which, as it seems to me, the Parallel Roads could not have been sea-beaches.

The principal difficulty which DARWIN and CHAMBERS had to contend with is the circumstance, that in each Glen there is proved to have been an old *river course*, by which *the waters of the lake flowed out to a lower level*.

When Mr DARWIN wrote his memoir, these old river courses had not been discovered. All that he knew was, that the shelves in each of the glens coincided with a col or summit level which separated the glen from some adjoining glen. Mr DARWIN stated, that in the Pacific Ocean, there were many cases where arms of the sea were divided or separated by a spit of sand, which was thrown up by tides or storms. He assumed that the highest shelf in Glen Roy was on the same level as the highest in Glen Gluoy, and that the sea may have stood at the same level in Strathspey. Mr DARWIN, when he made his survey, laboured under two great disadvantages. He had no spirit-level with him, and he did not visit the Pass of Mukkoul, where there is the unmistakable river channel, by which Loch Laggan discharged itself into Strath Spey.

ROBERT CHAMBERS was not under these disadvantages. He and I had each a spirit-level, as well as a barometer and a sympysometer, by means of which we satisfied ourselves that the highest shelf in Glen Roy was at least 12 feet below the highest shelf in Glen Gluoy. In fact, he was the first to detect the appearance of an old river course between these two glens. In his "Ancient Sea Margins," he alludes to the joint survey which he and I made, and also to the Memoir read by me in this Society, and which appeared in our Transactions before his book was published. He takes no notice of the facts stated in my Memoir regarding these old river courses, though so conclusive against the marine theory which he had adopted. He, however, oddly enough makes the following admission regarding one of the lakes:—"The Pass of Mukkul," he says, "the

supposed outlet of the lake of No. 4 shelf, presents the *appearance of an ancient river course*, a flat passage of seventy feet wide, confined by wall-like rocks, *which seem water worn*" (p. 112), and this statement is actually accompanied by a woodcut representing this *ancient river course*.

No doubt he only says that this Pass presents the *appearance of an ancient river course*. But he does not state how the appearance could be explained on any other principle than as the outlet of a lake.

Professor NICOL, as I have already said, expresses an opinion that at none of the cols is "there the slightest trace of an ancient river," adding, that "there are indications of the *passage of water*, as through a narrow sea strait."

But the substitution of "a narrow sea strait" for a "river" is impossible, if the levelling by the Ordnance Surveyors is to be trusted, proving that the water in Glen Gluoy stood twelve feet higher than the water in Glen Roy, these two glens being connected by the passage referred to.

2. Another difficulty with which Mr DARWIN and his followers have to contend is suggested by the flatness of the ground which forms the shelves.

On the sea-shore, where the tide rises and falls, the materials which collect on the beach undergo an action impossible in a lake. The beach must slope more or less from high water towards low water mark. But in the Lochaber shelves there is hardly any slope. ROBERT CHAMBERS in his book (p. 98), gives a woodcut, which shows the flatness of the shelves. (See also fig. 17, p. 51 hereof.)

3. There is another feature which distinguishes the "Parallel Roads" from sea-beaches. There are ancient sea-beaches along our coasts at eleven, twenty-five, and forty feet above the sea, not to speak of others at higher levels. These old "Sea Margins," as CHAMBERS called them, even the lowest and most recent, are *faintly* impressed on the land. But if the Parallel Roads are sea beaches, how much more ancient must *they* be, if height above the sea is any measure of antiquity; and therefore, how *much less distinct and less continuous ought they to be?* Now, what is the fact? Undoubtedly, these "Parallel Roads," at heights exceeding 1000 feet above the sea, are *much more distinct, continuous, and perfect, than any ancient sea-margins*, even the lowest and most recent, which can any where be pointed out.

4. But whilst I cannot accept Mr DARWIN's explanation of the Parallel Roads, I am free to admit that there are other markings on the hills of Lochaber which may possibly be ascribed to the sea.

ROBERT CHAMBERS in his book was the first to indicate certain lines more or less horizontal on Ben Chlunaig, and also on Craig Dhu. He thought that some of those corresponded in level on the opposite sides of the valley, and on this ground he pronounced them to be "ancient sea-levels."

That such lines exist, I can vouch for, having viewed them from various distant points, and having measured the heights of several.

I requested Sir HENRY JAMES to authorise his surveyors to mark on the Ordnance Maps such of these lines as they could recognize as resembling the Parallel Roads. Accordingly, I observe that in the last edition of the Glen Spean six-inch scale map, one of these lines, 1306 feet above the sea, has been represented on "Craig Dhu." It runs continuously for more than half a mile. There is another on the east side of Glen Roy, opposite to the side valley called the "Gap" and Ben Erin, at a height of above 1200 feet.

CHAMBERS, in his book, specifies other lines at 1337 and 1495, which he says "are so bold, that I cannot but wonder at their not hitherto having attracted any special attention."

Mr JOLLY, of Inverness, has within the last three years, not only verified these observations of CHAMBERS², but has discovered on Ben Chlinaig lines of a similar character, exceeding 1700 feet above the sea.

The height of the shelf represented by the Ordnance Surveyors, as occurring on "Craig Dhu," at 1306 feet, does not agree with the heights given by ROBERT CHAMBERS or by Mr JOLLY for any corresponding line on Ben Chlinaig. Therefore, it cannot at present be assumed that these lines on the two sides of the valley, where opposite to one another, correspond in level. CHAMBERS' chief reason for pronouncing them to be sea-beaches, has therefore not yet been verified.

I may mention that there is also a line on Ben Erin (situated between Glen Roy and Glen Gluoy), which my brother the Admiral, who accompanied Mr JOLLY and me on a visit three years ago, was the first to notice. This I judged to be about 1877 feet above the sea, when viewing it as I did repeatedly from Craig Dhu and Ben Chlinaig.

With regard to the character and origin of the lines on Ben Chlinaig, Craig Dhu, and Ben Erin, now referred to, I am unable to give an opinion. They may have been formed by the sea as CHAMBERS supposed; but, whether they were beaches or submarine banks, is a question depending for its solution on further investigation. I regret that more of these anomalous lines, if examined by the Ordnance Surveyors, have not been represented on their maps. Their position on both sides of Glen Spean, and nearly opposite to one another, gives to them peculiar interest in reference to the way in which they could be formed, when the glen was a sea passage.

One thing seems tolerably certain, that these lines are quite different in character from the "*Parallel Roads*." On that point Messrs JAMESON and JOLLY have expressed an opinion in which I quite concur, though I do not concur in considering them to be the moraines of glaciers.*

* Since this paper was read, I have had an opportunity of walking along the line, shown on the 6-inch Ordnance Map at a height of 1306 feet on Craig Dhu. It extends for about half a mile on the part of the valley above Achleureuch and Mullaggan. It certainly has none of the characters of a

Besides the lines to which I have adverted on Ben Chlunaig, Craig Dhu, and Ben Erin, and which may very probably be ascribed to sea agency, there are other appearances in the district which may have a similar origin. I allude to the extensive terraces and cliffs at lower levels, which certainly imply the presence and prevalence of large bodies of water, marine or lacustrine.

Thus at and above the Roman Catholic Chapel in Glen Spean, there are terraces, apparently horizontal, at 717 feet, 558 feet, 458 feet, and 409 feet above the sea. On the hills between Spean River and Fort William, there are flats, as ROBERT CHAMBERS points out (p. 94), at a height of about 391 feet above the sea, consisting of gravel and sand, in stratified beds, which strongly betoken sea action. But these flats are manifestly quite different in character from the true Parallel Roads, and (in my view) afford not the slightest argument in favour of the opinion that these "*Roads*" are marine.

I turn now to the

Ice Barrier Theory.

This theory is the one which has received the greatest number of supporters. First suggested by AGASSIZ, it has been accepted by Mr JAMES THOMPSON of Glasgow, Sir CHARLES LYELL, Mr JAMIESON of Ellon, and Mr JOLLY of Inverness.

1. Mr JAMIESON'S paper is published at length in the "Journal of the London Geological Society" for 21st January 1863. Mr JOLLY'S paper was read before the Edinburgh Geological Society on 17th April 1873, and an abstract of it is given in that Society's "Transactions." I had the pleasure of hearing the entire paper read, and I have since been kindly allowed an opportunity of reading and studying it.

Both of these gentlemen suppose that glaciers were formed in three several places, viz.,—(1.) In the hills situated at the head of Loch Arkaig. (2.) On the north-east flank of Ben Nevis; and (3.) In the hollow between the hills now occupied by Loch Treig.

With reference to the barrier which crossed the Unichan district, between the lowest shelf at Teindrish and the corresponding shelf at Corrychoilzie, Mr JAMIESON makes the following statement;—

"The extension of the lake was cut off here by a glacier issuing from Corry McEoin, and on the opposite side by the ice of Glen Arkaig, and the Great Glen, flowing over to near Teandrish. This would close up the mouths of Glen Gluoy and Glen Spean, and so long as the ice exceeded sufficiently the height of the water-sheds at the top of the glens, these cols would determine the level of the water in the lakes (p. 247).

"But in Glen Roy there are three lines;—and this barrier across the mouth of Glen Spean,

Parallel Road, but several features which indicate sea action. There is an accumulation of *débris* from the rocks above, forming a sort of terrace. The terrace is not horizontal towards the valley. It slopes rapidly from the hill.

although it might serve for the lowest, leaves the two higher ones unaccounted for. In order that a lake in Glen Roy could exist at the height of the upper lines, something must have prevented the waters escaping by Mukkoul, and also by the Glen Glaster col.

"In order to explain this, we must go to Loch Treig. Let us suppose a glacier issuing from the mouth of Glen Treig, and let it protrude *across* Loch Spean until it rests on the hills upon the north side of that valley.* This would cut off all outlet to the eastward, both *by Glen Glaster† and Mukkoul*, and so long as the icy barriers maintained a sufficient height, the water filling Glen Roy would have to escape by the col at the top of that glen into the head of Strathspey.

"Now let the Glen Treig glacier shrink a little. This would open the Glen Glaster col, and let out all the water above its level.‡

"Then let the Glen Treig glacier shrink again, until it withdrew out of Glen Spean. That valley being now clear, the water would escape by the outlet at Mukkoul, which would then determine the level of the lake and keep it at the lowest line, so long as the ice stream across the mouth of Glen Spean maintained itself of sufficient height.

"Grant then these two ice streams, one in the Great Caledonian Valley, and the other in Glen Treig, and the problem of the Parallel Roads can be solved, provided we allow that glaciers have the power to dam such deep bodies of water as must have occupied Glen Gluoy and Glen Roy."

Mr JAMESON explains how he supposes the different ice streams moved. Thus, with regard to the Arkaig glacier, he says that he found on the rocky

"Ridge between Loch Lochy and the Spean, such markings as might be made by ice mounting over it from Loch Lochy. The rocks were bare, where the presence of a glacier wheeling round from the Great Caledonian Valley into the mouth of Glen Spean, would have operated most strongly" (p. 246).

Mr JAMESON, at the conclusion of his paper, makes the following candid admissions :—

"The greatest difficulty that I find in supposing the parallel roads to have been formed by glacier dammed lakes, arises from *a consideration of the depth of water the ice had to retain*; for it is evident that the moraines were too insignificant to have done much of the duty. One might think that by the hydrostatic pressure of a column of water some hundreds of feet high (the water) would have found an *escape beneath the ice*. If, however, the height or thickness of the glacier were sufficiently in excess of the depth of the water, I imagine there would be pressure enough to keep it in" (p. 257).

Mr JOLLY adopts Mr JAMESON'S views regarding the existence of a glacier in each of the valleys of Arkaig, Corry M'Eoin, and Treig. He, however, suggests an additional glacier from the valley of the Laire (adjoining Loch Treig on the west) which filling Spean valley might flow down towards the west.

"If (says he) a glacier issued from Corry M'Eoin, and added its tributary ice to the Spean

* If Loch Spean existed at this time, of which there can be no doubt, it is difficult to understand how a glacier could protrude across it, in the very middle of the Loch.

† To do this, the glacier must have filled Glen Glaster, and crossed the valley of the Roy.

‡ The level here referred to is that of Shelf 3. If the ice shrunk back from Glen Glaster, there would be no ice barrier across Glen Roy for Shelf 3, which extends down that Glen, beyond the mouth of Glen Glaster.

glacier, the ice would likely push itself across the Spean into the mouth of Glen Roy, and up Glen Collarig" (MSS. p. 25).

The existence of an ice stream which passed from Loch Treig through Glen Glaster, Mr JOLLY thinks is proved by the existence in that glen of what he considers to be moraines. These, he says:—

"Prove the presence of ice at the head of Glen Glaster to dam back the water of the middle shelf in Glen Roy. They also point to an extension of the ice in that glen above the middle shelf to form in conjunction with the glacier extensions from the glens west of Ben Chlinaig, the required dam for the highest shelf in Glen Roy at Cranachan, where that shelf suddenly ends on both sides of the glen" (MSS. p. 29).

2. Having thus explained in what manner the ice dams are supposed to have been formed to suit the different glens and levels, and from what sources the ice came to make these dams, I proceed to notice the difficulties which this theory has to contend with.

(1.) Is it likely that in this Lochaber district, some of the glens should have been filled with solid ice and others with water?

The temperature must have been much the same in all the glens. If there was any difference, one might have supposed that in the glens furthest from the sea, in winter at least, there should have been more cold; and yet Glens Gluoy, Roy, and Spean, which were occupied by lakes, are farther from the sea than Corry M'Eoin and Loch Arkaig, which are supposed to have supplied great glaciers.

There is only one case in the known world of a lake among mountains the waters of which were dammed up by a glacier. The Marjelen See in Switzerland, is a small lake occasionally dammed up by the Aletch glacier, as it flows past one end of the lake. This lake is at a level of 7000 feet above the sea; and the glacier comes from hills having a height of 12,000 feet above the sea. In this case, it is therefore intelligible how there should be a lake at the one place, and a glacier at the other. But in the Lochaber district, there is no such difference of altitude to cause a greatly lower temperature in the glens where Messrs JAMIESON and JOLLY say that glaciers were formed.

Indeed, some of the hills adjoining Glens Gluoy, Roy, and Spean, are quite as high as the hills from which the glaciers are supposed to have come.

(2.) Another difficulty is suggested by the levels of the country.

The barrier for the highest shelf in Glen Gluoy must have been at a height of 1170 feet above the sea. But the valley of Arkaig is only about 200 feet above the sea, and if a glacier emerged from its mouth, it would naturally flow westward towards the sea, instead of climbing 900 feet up a steep hill on the opposite side of the valley.*

The highest shelf in Glen Roy being 1150 feet above the sea, the Treig

* There is a very instructive paper "On the Parallel Roads," by Mr JAMES BRYCE, junior, F.G.S.
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glacier would have a less rise to make, because Loch Treig stands at a level of 750 feet above the sea. But its course towards Cranachan, in Glen Roy, would be so obstructed, as to render it impossible that it should ever have reached Glen Roy at the place required, in the condition of a solid body of ice. *First*, it would have to descend into Glen Spean, (which must there have been filled by a lake flowing out at Muckoul) which is about 200 feet below Loch Treig, and then it would have to climb up the ridge separating Glen Spean from Glen Glaster, requiring a rise of 500 feet, in which case it would have risen above its own fountain head to the extent of no less than 400 feet. After getting over this ridge it would, before it could reach Glen Glaster, have to *wheel round* the S.E. corner of Craig Choinichte, and on passing through Glen Glaster make another bend before it reached Glen Roy. Even if, on reaching Glen Roy, it struck against Bohuntine Hill, and did not flow down Glen Roy, is it possible to suppose that the ice, on reaching Glen Roy, could have formed a *solid body* sufficiently strong to resist "the hydrostatic pressure of a column of water some hundreds of feet high?" This difficulty, suggested by Mr JAMIESON himself, seems to me insurmountable.

(3.) There is a further difficulty. The lake of Glen Roy, at the middle shelf, discharged through Glen Glaster; but if the Treig Glacier came through Glen Glaster to block Glen Roy for Shelf 3, as suggested by Messrs JAMIESON and JOLLY, any overflow of the lake through that glen would be impossible.

(4.) Mr JOLLY thinks that the barrier in Glen Collarig for Shelves 2 and 3 might have been made by the glacier from Corry N'Eoin pushing across the Spean into the mouth of Glen Roy and up into Glen Collarig. To say nothing of the very tortuous course which the ice would have to take before it could reach the middle of Glen Collarig, it is enough to observe that a glacier coming out of Corry N'Eoin must, in virtue of the existing levels of the country, have flowed in an exactly opposite direction. The only use which Mr JAMIESON made of the Corry N'Eoin Glacier was to find a dam for the lake of Shelf 4, which extended down to Unichan. He supposed that this glacier extended across the Unichan Moor in a strait line to Teandrish. But as this barrier required to be four or five miles in length, it is hardly possible to suppose that this Corry N'Eoin glacier could have formed a solid barrier along its whole course. Every winter and every summer it must have changed its position and its internal structure, in such a way as to allow the water to escape through or under it.

(5.) Reference has been made to the Marjelen See. This lake, as I have just observed, is very small in size. Sir CHARLES LYELL, who visited it in the year 1865, says it was only two miles in circumference. Professor FAVRE, of

(published by the Philosophical Society of Glasgow in 1850). Mr BRYCE shows from the geographical position of Loch Arkaig that even supposing a glacier to have been formed in that valley, any moraines which it might have produced, could not have been so situated as to block Glen Gluoy. He does not think it necessary even to entertain the question of a blockage by the glacier itself.

Geneva, informs me by letter that its greatest length is 1400 yards; its width 430 yards; and depth, next to the glacier, 114 feet.

The Aletch Glacier, in a solid mass, flows past one end of the lake, and presents a wall of from thirty to forty feet above the lake, when it stands at its normal height, forming a solid mass of ice, therefore, of about $114 + 40 = 154$ feet altogether. The normal height of the lake is determined by its discharge over a col, at the opposite or east end, into the Viesch Valley.

But though this great Aletch Glacier flows past one end of the lake in a solid mass, does it succeed in damming the waters permanently? Berlepsh, in his "Guide to the Swiss Lakes and Glaciers," describes the Marjelen See particularly. He says (page 484):—" *Tous les ans, en juillet ou en août, le lac se frage un chemin, sous le glacier d'Aletch, et se verse par le Massa près de Naters sur le Rhone.*"

The case of the Marjelen See, therefore, presents features which entirely distinguish it from Glen Roy. If even the solid body of the great Aletch Glacier is not sufficient to prevent the water escaping under it, how still more improbable would it be in the case of a dam formed by the tongue of a small glacier formed in a small Lochaber glen? If the solid body of the Aletch Glacier is unable to dam permanently a lake only 114 feet deep and 430 yards wide, how is it possible to suppose that merely the tongue of a glacier from the Treig Valley—a tongue wending its way across valleys and round hills for five or six miles, could dam a lake such as that which filled Glen Roy?

It seems really almost impossible to believe that a glacier formed in any of these Lochaber corries should have produced tongues of ice more than twice as long as the glaciers themselves, and that these tongues should, at their tips, have formed permanent ice barriers.

Mr JAMIESON brings together, to form his ice barrier for Shelf 4, no less than three tongues,—one from Corry M'Eoin, one from Arkaig, and one from the Great Glen. The meeting of these three ice tongues, coming from opposite directions, would be a very remarkable conjunction indeed, if it had the effect of producing a solid barrier of ice!

(6.) All the writers who adopt the ice dam theory, feel the necessity of having a glacier from Loch Treig to supply a barrier for the lake in Glen Roy. But what if it should turn out that the Treig Valley, instead of being filled by a glacier at this time, was filled by water? Mr JAMIESON says, that had there been any of the "Parallel Roads" in Corry M'Eoin, from which the required glacier was supposed to come, he would have considered it a good objection to AGASSIZ'S ice theory (p. 246, "L. Geol. S. Journal" for 1863).

Now, there is a Parallel Road, or what is equivalent to it, in Loch Treig.

Sir THOMAS DICK LAUDER says, in his Memoir (p. 43), "Edin. R. S. Trans." vol. ix., year 1823), that the lowest shelf, called by him No. 4, as it approaches

the "River Treig, sweeps round in the direction of the mouth of the glen and lake of that name. It enters the jaws of the pass *into Loch Treig*, in the manner represented in plate vi."

AGASSIZ and CHAMBERS also attest the existence of a shelf in Loch Treig.

Last October, in company with the Rev. Mr CAMERON of Kilmonivaig, I walked along the south bank of Loch Treig for about two miles from its mouth.

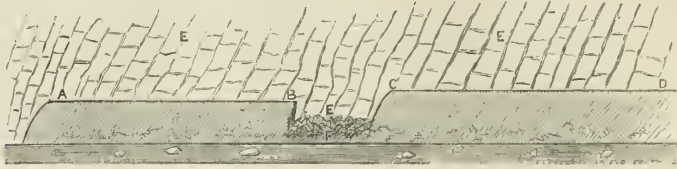


Fig. 14.

Section of north bank of River Treig, to show two terraces or shelves, CD being supposed to be Shelf 4, AB being a separate shelf or water-line, from 25 to 30 feet lower.

We made the following discoveries:—

The lowest shelf, viz., No. 4, we thought was recognizable at one place on the east bank of the loch—two miles from the north end. It was formed on



Fig. 15, (pp. 630 and 641)

B is Loch Treig. C are rocks on the south bank, about half a mile from north or lower end of Loch. A is a bed of stratified white sand, much frequented by rabbits. Its surface is about 40 or 50 feet above the lake. A Boulder 5 feet high and 2½ wide stands partly buried in the sand.

a bed of detritus. This, however, was only an inference from the fact of there being a flat bit of detritus at the same height above the lake as Shelf 4,—viz., 91 feet. In looking across the lake we observed a similar flat at a corresponding level on the opposite bank.

At the entrance of Loch Treig I found what is shown on figure 14, where CD is Shelf 4. It stops about 100 yards from the entrance to the

loch. About twenty-five or thirty feet below the level of that shelf, there is another shelf, A B, which is situated between the termination of Shelf 4 and the lake, and of which we found traces on both banks of Loch Treig itself. This lower shelf is indicated by isolated flats consisting chiefly of a sandy mud, from 40 to 50 feet above the level of the lake. These flats have, no doubt, been originally continuous, and have been cut through, and somewhat reduced in level by the action of rain and of streams from the steep hills which surround the lake. One of these flats, consisting of a white sand horizontally stratified, full of rabbits, with a remarkable boulder sticking in it, is indicated by fig. 15.

Between these two shelves, viz., between B and C, rock is visible in the channel of the river and close to its brink, covered by drift E. This lower terrace occurs on both sides of the river, as shown on fig. 16.

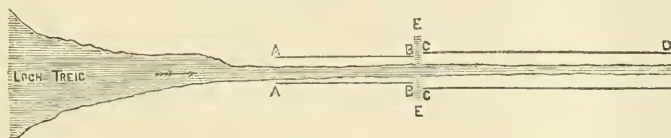


Fig 16.

Ground plan of River Treig, near Loch Treig, showing position of two horizontal water-lines or shelves on both sides of the River. CD is Shelf 4, AB is a water-line from 25 to 30 feet lower in level.

I observe that Mr JAMIESON states ("Lond. Geol. Journ.," vol. xix., p. 250), that at the mouth of Glen Treig he discovered a terrace thirty feet above No. 4 shelf.

There is thus a good deal of more precise observation required to clear up these Loch Treig terraces. But one thing is very clear. So far from there having been a glacier in Loch Treig *when Shelf 4 was forming, Loch Treig must, since there are horizontal water terraces at its mouth, up to 90 feet above its present level, have been full of water*; and if it was full of water when Glen Roy lake stood at No. 4 shelf, why should it be supposed that it was not full of water when the same lake stood at higher levels?

The probability is, that the mouth of Loch Treig at that time was blocked with gravel, but yet not to such an extent as to prevent the waters of Shelf 4 entering it, and that when the Glen Roy lake fell from Shelf 4, a barrier of some kind, rock or detritus, existed at or near the mouth of Loch Treig, which for some time kept its waters up to the height of shelf A B, *i.e.*, about 40 or 50 feet above the present level of the lake.

I referred to a remark of Mr JAMIESON's, that if any of the Parallel Roads had been found in Corry N'Eoin, he would have considered it a good objection to the theory of AGASSIZ, which required a glacier to come from Corry N'Eoin to provide a barrier at Unichan for Shelf 4.

I examined the mouth of this Corry very carefully. I had not time

to go into the Corry itself; but on each side of its mouth I saw large knolls of detritus. Now, is it possible to suppose that these knolls and hummocks would not have been obliterated by any glacier large enough to protrude a tongue five miles long across Unichan to Teandrish? The fact, therefore, that one of the parallel roads comes close to Corry N'Eoin, and that these knolls and hummocks of gravel are standing at its entrance, suggest to the theory of AGASSIZ an objection quite as strong as if there had been a Parallel Road inside of the Corry.

(7.) The chief proof on which Mr JAMIESON and Mr JOLLY rely for supposing the occupation of Loch Treig by a glacier, is the existence of long curved banks of gravel and boulders in the Valley of the Spean, which they consider to be indubitable moraines. Mr JAMIESON says, in respect of these gravel banks, that ("Lond. Geol. Soc. Journal," 21st Jany. 1863, p. 247): "The evidence for the Glen Treig glacier is probably more complete than for any other glacier in the kingdom."

I confess that when I first saw these banks of gravel and boulders, viewing them as I could then only do from a considerable distance, I adopted the idea, and expressed it to Mr JOLLY, who was then with me, that they were moraines, and probably formed by a glacier in Loch Treig.

I have now changed my opinion on this point, in consequence of several more minute surveys of the ground.

The gravel banks alluded to are situated on both sides of the Spean Valley, a little to the east of Glen Treig.

The plan (on Plate XLIII.), copied from the Ordnance Survey Map, shows these banks in red colour.

In the first place, it will be observed that portions of Shelf 4 have been formed upon these banks. The banks, therefore, must have existed before the shelf was formed. As this fact is of importance, I may observe that, three years ago, I satisfied myself that it was so; and the Ordnance Surveyors, judging only by the appearances on the ground, came to the same conclusion. The shelf is, no doubt, much broken in continuity, owing to the rough character of the materials on which it has been impressed, and to the number of streams which have cut through the shelf since its lake was drained off. But the fragments of the shelf impressed on the banks are sufficiently numerous to leave no doubt that these banks must have existed previously to the formation of the shelf.

Mr JAMIESON admits that Shelf 4 *has been formed on these moraines*, as he terms them. Referring to "the *terminal moraines* of Glen Treig," he says that "at Inverlaire and around the large rocky knoll called Tom-na-Fersit," they have "*been finely terraced by the action of the water, when at the level of the lowest Glen Roy line*" ("L. Geol. Soc. Proc.," vol. xix. p. 249.

Therefore, if these banks are the moraines of a glacier from Loch Treig, *that glacier could not have existed contemporaneously with the lake of Shelf 4. The lake must have been formed after these so-called moraines were formed, and after the glacier which produced them ceased to exist.*

The idea that these banks were moraines was suggested, probably, by their curved forms. When glaciers protrude from a valley, they often carry rubbish and boulders on their surface, which, on reaching the lowest end of the glacier, are projected over its surface as the glacier melts; and should the glacier at some future period push forward again, they are, by the pressure of the glacier, formed into a bank, which has somewhat of a crescent or horse-shoe form, the concave side being, of course, towards the glacier.

In examining the Ordnance Map, it will be seen that there are some very remarkable curved lines dotted over with boulders, but that only a few of the curves face Loch Treig.

If any inference is to be drawn from the aspects of the lines, they point rather to some agency which has come up Glen Spean Valley. Now, there is strong evidence to show that an agent of some kind did come up this valley, and on its way up acted with tremendous power. The hard rocks on both sides of the valley, where the valley is narrowest—viz., near the Roman Catholic Chapel and at Murlaggan—have been ground down, smoothed, and polished. These are well seen, at five or six places between the chapel and the junction of the high roads to Laggan and Loch Treig.

Most of the surfaces of rock so polished, slope *down*, and, as it were, *face down* the valley, and the striæ upon them run W.N.W. and E.S.E.—being a direction parallel with Glen Spean valley. There are very few smooth surfaces of rock which face or look *up* the valley, and *these few are not striated.*

Near Achleureuch Post-Office a clay slate rock, sloping down the valley, presents very large smoothed surfaces. It so happens that the rock there contains many nodules of white quartz, which stand up above the softer rock, having better withstood the grinding. These quartz nodules have been beautifully polished on their sides or surfaces *which face down the valley*, indicating clearly that some body or bodies passed up the valley, pressing severely its sides, and grinding, smoothing, and striating the rocks.

Other localities may be mentioned in Glen Spean. Thus, near Inverlair Bridge there are several rocks with striæ on them, running N.N.W. At the junction of the Inverlair and Loch Laggan roads, there is a rock showing striæ W.N.W.

These directions are quite at variance with the notion of an outflow from Loch Treig, and indicate a movement *through, parallel with, and up* Glen Spean valley.

As the facts now referred to are important in their bearings on this

question, I may refer, in confirmation of the foregoing statements, to the testimony of Professor NICOL of Aberdeen, and the more so that he does not agree with me in my way of solving the problem. He says—

“The detritus has *not* come *down* Loch Treig, as might at first sight be imagined, but from the Corry Laire, to the west; and has then been *swept eastward* by tidal currents, and *even up into Loch Treig*, on which it abuts, with a bold, almost vertical end. In many other places in this part of Glen Spean, there is similar evidence of a *current from the west flowing up the valley.*”—(Lond. Geol. Socy.” 21st May 1869, p. 288.)

Higher up Glen Spean (as at Carbeg and Moy) there are several places where smoothed rock surfaces occur, sloping towards the west, with numerous parallel striæ, running at one place W. $\frac{1}{2}$ N.; at another, W. by S.

There is, on the north side of the road, a mass of hard granite rock, rough on its east side, ground down and beautifully smoothed on its west side.

At the Rough Burn there is a rock on the north side of the road, with a smoothed surface, dipping W.N.W., at an angle of 22°. Striæ run obliquely across its face from W. by S.

On the hill north-east of Rough Burn, 1600 feet above the sea, the rocks are smoothed on north-west sides, and are rough on opposite sides. There are quartz nodules in the rocks about 8 inches square, which are smoothed only on their west sides.

All these facts tend to show a movement up Glen Spean, and not down from Loch Treig.

Mr JAMIESON, whilst he thinks he saw evidence that ice had passed down the Spean valley in its lower part, admits that in the upper part of Glen Spean Valley it is

“The *west* side of the rocky masses that has sustained most abrasion. Far away, even to the end of Loch Laggan, I traced the same appearances. Beyond the Pass of Makoul the low rocky eminences show evident traces of the passage of ice, *going out towards the valley of the Spean.*”—(Lond. Geol. Socy. Journal,” 26th February 1862, p. 173.)

The places before referred to of rocks ground and striated in Glen Spean, are along the whole course of the valley near the bottom. But higher up on its sides similar appearances exist.

Thus Craig Dhu, on the north side of Glen Spean, near the foot of the valley, reaches to a height of 2161 feet above the sea. On the *west* and *south* aspects of the hill, I found the rocks bared and smoothed to a height of about 1800 feet. The rocks on *north* aspects of the hill were rough. At two places, striæ were observed by me, and their direction in both cases was W. by N. At the part of the hill next Glen Glaster, the rocks were smooth on the *west* side; rough on the *east*. There was a large surface of rock, dipping at

an angle of 50° degrees towards west. Striæ were on this rock, and *these striæ* were *horizontal*. Within a few yards of the top of Craig Dhu, the edges of the strata running north and south were all ground down on the *west* sides, and remained rough on their east sides.

Ben Chlinaig is opposite to Craig Dhu, being on the south side of Glen Spean. Mr JOLLY found, on the side facing the valley, striated rocks at a height of 1750 feet above the sea, the striæ running S.E. and N.W., or parallel with the valley at this place.

About two miles further south, in the Laire valley, at a height of 1600 feet above the sea, Mr JOLLY found, on a rock surface, striæ 50° W. of north.

Mr JAMIESON examined the rocks at the outlet of Loch Treig, and found the rocks smoothed at a height of 1000 feet above the Loch, and 1740 feet above the sea.

“One bare flat surface of gneiss, thirty yards long, beautifully smoothed, and covered with parallel scratches, scores, and flutings, running straight from end to end.” Elsewhere,—“*Striæ running horizontally along the faces of the rock*, were traced up to 2000 feet. Not that I affirm even this to be their upper limit.” He mentions other appearances, even as high as 3055 feet above the sea, which “raise a suspicion, that some denuding agent has flowed over it at a period geologically recent.”—(“Lond. Geol. Socy. Journal,” 26th February 1862, p. 172.)

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Unfortunately Mr JAMIESON does not mention the direction of the parallel scratches and flutings described by him. But it is not unimportant to observe his statement, that “along the faces of the rocks” they were “running horizontally.”

In connection with Loch Treig, I may mention that in company with Mr JOLLY and my brother, I walked from its mouth due east along the side of the hill, at a height of about 1600 feet above the sea, and at a distance of about a mile, we came on a large mass of rocks, projecting from the hill side. These rocks, presenting high vertical faces, at once arrested our attention. On their *west* sides they were rounded and smoothed, as if by some heavy body or bodies which had rubbed and pressed against them. On their *east* sides they were rough, as if these sides had been protected, *i.e.* not subjected to the action of the rubbing agent. At the foot of these rocks there was an enormous accumulation of large boulders. The agent, whatever it was, which had been rubbing the rocks, seemed to have brought the boulders and dropped them there. These rocks are at a height of about 1500 feet above the level of the sea, as shown by the O.S. contour lines.

The foregoing remarks apply to markings on the *rocks* in Spean Valley. But it is also proper to refer to the *banks of gravel and boulders* on the hill-side to the east of Loch Treig.* They run along the hill-side in an east and west direction. Near Loch Treig there are eskars, at the several heights (by

* See Plate XLIII.

Aneroid) of 1120 feet, 1165 feet, 1175 feet, and 1489 feet above the sea. With regard to the uppermost, I extract the following from my notes. "It is composed of detritus, with boulders on top. At west end it is a terrace nearly horizontal, but towards east it separates from hill side and becomes an eskar or kaim. The rains and rivulets descending on it from the higher part of the hill, may have scooped out the trench along the south side, which lies between it and the hill. Towards east, this kaim ceases to be horizontal, and slopes down rapidly towards the plain, still retaining the form of a bank." On the top of this highest flat, as well as on the lower flats, there are several large boulders. But above the highest flat we saw other boulders on the hill at a distance, which we had no time to visit, apparently about 1800 feet above the sea.

On a lower part of Spean Valley there are similar banks of detritus up to even greater heights. CHAMBERS characterized them as "sea beaches." Messrs JAMIESON and JOLLY look on them as the lateral moraines of a glacier which descended from the valleys of the Treig and Laire. I examined several of these banks, and agree that they are in no respect "Parallel Roads." Mr JOLLY in his paper admits that they have a great resemblance to "kaims,"—that is to the well-known long banks of gravel which abound elsewhere in Scotland. On Ben Chlinaig, at the lower part of Glen Spean, where the valley is exceedingly narrow, there are several of these kaim-like banks running along the side of the hill. Mr JOLLY describes them correctly when he says that these banks are continuous only "for short distances." "They are not absolutely horizontal, but rise and fall on the hill sides (JOLLY MSS. p. 15). One of these "kaim-like banks" on Ben Chlinaig, opposite to Craig Dhu, I found by aneroid to be 1253 feet above the sea. I crossed several others up to a height of about 1700 feet above the sea. When not horizontal, they seemed to slope down slowly towards the east."

Between Ben Chlinaig and Loch Treig, there is the wide valley of the Bruach, in which there are many eskars or kaims running in various directions. Some of them are straight, others are curved. A view of these is attempted to be given in fig. 2 (p. 668). There is another long eskar, immediately above Tulloch House, which runs on an elevated plateau in a direction north-east and south-west. At its lower end, next the River Spean, there is on it a huge boulder, at a height of about 1057 feet above the sea. As the general surface of the district rises towards the south-west, this eskar rises also and forms a continuous bank, with steep sides, for about a quarter of a mile in length. Its south-west end is 1200 feet above the sea. The eskar is composed of fine sand and small gravel.*

* Mr JAMIESON admits that in this valley the gravel is water worn. He says "at a deep section of one of these banks at the mouth of Corry Laire, I noticed that the mass consisted of coarse water worn gravel, very pebbly; the pebbles indicated a certain amount of water rolling."

Author's Views.

In reference to the phenomena last described, which Messrs JAMIESON and JOLLY have sought to explain on Glacier principles, I venture to propose an explanation of a different character.

It occurs to me to suggest whether these phenomena rather do not indicate the action of ice floating in a sea at least 2000 feet above the present sea-level? If Glen Spean then formed a Kyle or submarine valley, the floating ice would grate upon the sides of the hills, and plough through the detritus covering them, and occasionally form troughs and banks, more or less parallel with the valley. The markings on the rocks where the valley is narrow evidently indicate some powerful agency, such as an iceberg. At the Bruach Valley, where there would be a bay in this ancient sea between Ben Chlinaig on the north and the rocks of Meal Laire and Loch Treig on the south, there might have been eddies, which would account for the large accumulation there of gravel and sand in the form of long embankments.

See 200

Farther east, Glen Spean becomes somewhat more contracted by the projecting rocks at Loch Treig on the south side, and the Coinnichte Hill rocks on the north side. But beyond that point, it will be observed from the Ordnance contour lines* that the valley expands greatly, especially towards the east. A current flowing eastward through the narrow part, between Ben Chlinaig and Craig Dhu, when it reached the part beyond Inverlair and Loch Treig, would become almost stagnant, or form slow eddies. The probability is, that any current coming up the valley from Ben Chlinaig would strike on the projecting rocks east of Glen Treig, and if there was ice floating in the current it would impinge on these rocks and throw down at the foot of the rocks the boulders now lying there in heaps. (See p. 641.)

The foregoing remarks apply to Glen Spean, but similar facts are supplied from other adjoining districts.

In the upper part of Glen Roy there are hard grey granite rocks in the middle of the valley, which in my first memoir I noticed as affording evidence of some agent which had ground them down to a remarkable smoothness of surface. These rocks have been smoothed on their *west* sides, and are rough on their *east* sides. Had a glacier ever existed in Glen Roy, these rocks would have been smoothed on their east sides, and been rough on their west sides. This fact favours the theory I have advanced of a sea laden with ice, which, besides flowing up through Glen Spean had flowed also up through Glen Roy, then a submarine valley.

In another part of Glen Roy, viz., on the south side, nearly opposite to the Gap, and at a height of 1238 feet above the sea, I found rocks with smoothed

* See Plates XLI and XLIII.

surfaces facing the west, indicating a movement also over them from that quarter.

Mr JAMIESON ("Lond. Geol. Soc. J.," 26th Feb. 1862, p. 176), had observed the appearances in Glen Roy now referred to, and admits his perplexity with reference to their bearing on his glacier views. He says, "I was not a little surprised, to find it quite apparent, that the ice had come from the south-west *up* Glen Roy, and gone out in a stream towards the wide valley of the Spey." He also admits having, in the same part of Glen Roy, discovered other rocks, "so blunted and rubbed on their *south-west exposure*, as plainly to show that the movement came from *that* quarter."

In Glen Gluoy above Almaharry Farm-House, at a height of about 1300 feet above the sea, there are rocks presenting vertical faces towards the north-west, from 30 to 40 feet in height. These faces have evidently been smoothed by some agent moving past them from the west, the faces fronting that quarter being *smooth*, and the faces fronting the east, *rough*. If the sea stood at a height of say 3000 above its present level, there would be a passage several hundred feet deep at the head of Glen Gluoy towards Strath Spey.

On the hill between Glen Fintec and Glen Gluoy, at a height of about 1700 feet above the sea, a rock there is smoothed and striated,—the striae running about W. by N. No glacier coming down either of these Glens could have touched this rock. It was acted on by some agent which came from an opposite direction.

In connection with these facts, reference may be made to observations by Mr JAMIESON on the direction of striae on the hills lying between the mouths of Glen Spean and Glen Gluoy. He says, on the ridge between these Glens (called Strone-y-Var), he found that the rock-surfaces indicated a "pressure of ice *from the west*."

"At an elevation of 800 or 900 feet, glacial scoring occurs, pointing W. 5° N.; a little lower, W. 20° N., running not horizontally but up and down the slope, as if by *ice mounting* from Loch Lochy. Again W. 26° N., W. 45° N., W. 15° N., and W. 45° N. The *western* sides of the rocks being most worn, showed that the action had come from that side, and *not down* the Spean Valley." "At a place called Brackletter, on the south side of the River Spean, near its junction with the Lochy, glacial scores point due west, but still inclining a little to the north." ("Lond. Geol. Soc. Journ.," 21st Jan. 1863, p. 246.)

At the mouth of Corry N'Eoin, I found several places where there were rocks smoothed and striated. Thus at one place, the surface of a smoothed rock sloped down to N. $\frac{1}{2}$ W. at angle of 42°. The direction of the striae upon this rock was N.N.W. Some of the striae were 2 to 3 feet in length. From this place the projecting shoulder of the mountain called Anach More, situated 2 or 3 miles to the west, bore W.N.W., so that it would not intercept any agent moving or floating towards the striated rock.

3000

ice mounting
 over a glacier
 out of the sea
 where the
 hill.

At another spot near the mouth of this Corry, outside of it, I found a rock with two sets of striae. One set were in the same direction, N.N.W., the others were running E. and W.

These observations, as regards the markings on the rocks, seem to be irreconcilable with any glacier theories which have yet been proposed. A sea current flowing from a north-westerly direction, but with local variations caused by the direction of the hills, seems to me a more likely solution.

As still bearing on the question, there is another set of facts which deserve notice. I allude to the position of some of the boulders.

(1.) The height at which many are found is interesting.

I extract the following from my notes.—“On the summit of the hills at the head of Glen Roy, about 169 feet above the highest shelf (*i.e.*, 1320 feet above the sea), there are enormous (granite) boulders. Some rest on surfaces of bare rock; but traces of clay and gravel about them suggest that they may originally have been imbedded in drift, which has been since mostly washed away from under and about them.”

Mr DARWIN was much struck by the number, size, and composition of some of the boulders he saw between Glens Gluoy and Roy. One of the spots where he found several granite boulders was what he calls a “*hillock*” of gneiss, 2200 feet above the sea. The hillock was *separated from all other hills*, so that the boulders could not have rolled down from them. He refers also to the *summit* of a very sharp peak of gneiss (1600 to 1700 feet above the sea), on which he found a block of syenite with pink felspar. This peak is wholly separated from other hills. He did not see anywhere another boulder of this syenite, or any rock *in situ* resembling it. (“Phil. Trans.,” Vol. 129, p. 69.)

On the Wester Bein Hill, situated close to Loch Laggan, I found a *grey granite boulder* about 4 feet in diameter, resting on a flat shelf, about 1516 feet above the sea. The rocks of the hill here, are a *coarse red granite*. The side of the hill on which the boulder lies points W.S.W.

Mr JAMESON mentions several large boulders on or near the top of Craig Dhu, which is 2100 feet high. I was also at the top of Craig Dhu, and saw the boulders which Mr JAMESON examined. This hill is of *gneiss* rock, whilst many of the *boulders* are “of *syenitic granite*.”

Mr JAMESON adds:—

“What is remarkable is, that the largest and most angular are more numerous, *high up on the very brow of the hill*, than they are *farther down*. Thus one 12 × 9 × 6 feet lay only 130 feet below the hill summit; another was a magnificent block 15 × 10 × 6 feet.”

Mr JAMESON also found granite boulders on the *top of Bohuntine*, a hill 2000 feet high, situated between Glen Roy and Glen Collarig.

Mr JOLLY states (MSS., p. 10) that on the west side of Craig Dhu, he found

or any other

Emmett,
1320

2200

1600

1516

2100

2000

1800
a huge granite boulder some 60 feet round and 12 feet high at a height of more than 1800 feet above the sea.

Professor NICOL of Aberdeen says:—

“ I found huge blocks of *black granite* and smaller masses of *red porphyry* within a few yards of the *summit of Craig Dhu*, a conical mountain of *mica slate*. One block must weigh 40 tons. They are evidently ice-born masses, probably floated from far in the west.” (“*London Geol. Soc. Jour.*”, August 1869, p. 283.

3000
Sir JOHN RAMSDEN of Ardverikie informs me, that he has seen granite boulders on the tops of two contiguous hills, called Ben Sguth and Gealcharn, the latter exceeding 3000 feet above the sea. They are situated to the north of Loch Laggan.

2250
The Ordnance Surveyors, when examining the Stratherrick Hills, noticed that the *largest boulders* were often on *elevated* sites. In a Report by Captain White to the Royal Society Boulder Committee, it is stated that the highest hills in that district are about 2900 feet above the sea, and that large boulders were most abundant above a level of 2250 feet. (“*Roy. Society Proc.*,” 2d June 1873, pages 141 and 157.)

(2.) The following facts indicate the peculiar position of boulders.

800
1100
On the west side of Bohuntine Hill there are numbers of gneiss boulders, at from 800 to 1100 feet above the sea. Those whose length is greater than their width, generally lie east and west, their smooth end, which is also the narrowest, being towards west. They probably came from the west, as the lowest ground bears from the boulders west $\frac{1}{2}$ south.

Mr DARWIN takes special notice of the circumstance that the Ben Erin Hills of *gneiss* (1600 feet above the sea), on which he saw numbers of *granite* boulders, are completely isolated by deep valleys on each side of them, leading to the conclusion that the boulders must have been transported to their sites by “floating ice.” It struck him that the boulders were “*most frequently on the summits of little peaks—such as Meal Dherry,*” from the numerous cases of that kind which he observed.

At the head of Glen Glaster, on the N.E. part, there is a sort of amphitheatre from 1000 to 1200 feet above the sea, on which there are gathered a large number of gigantic grey granite boulders mostly angular. One is $18 \times 12 \times 4\frac{1}{2}$ feet. Another is 12 or 13 feet wide, 9 feet high, and 23 paces in girth. These blocks are not near any rocks, craggs, or hills, from which they could have fallen. They appear to have been somehow *transported* to their present position. The lowest ground, and the widest opening, by which they could reach it, bears from it W. by S. and W.S.W., the direction of Fort-William. It appeared to me, that the most probable explanation was, that ice had floated to this spot, which, surrounded by hills, except towards the west,

formed a sort of *cul de sac*, where the ice, arrested in its farther progress, and melting, dropped the boulders.

On Craig Dhu, the boulders, in so far as not rounded, have their longer axis, most frequently east and west in direction. The following notes from my Field Book (p. 41) refer to these:—"A little above the 1391 level, found boulder lying on bare rock here forming a flat surface, glaciated like the rest from W. by N. (At this time I was inclined to glacier views.) The boulder, therefore, must have come here after glaciation of rocks. Longer axis of boulder E. and W. Standing at it, and looking *towards west*, I see that a line *from that direction* clears all the hills, and that there is an opening for a current to have flowed from west towards and upon Craig Dhu. Found masses of white quartz rock glaciated from *west*. A boulder lying on top of this rock, with longer axis W. by S. At a level of 1751 feet, found boulder with longer axis W. by S. Near Glen Glaster Col, 1445 feet above sea, boulder with longer axis W. by S. Another, $8 \times 4 \times 4$ feet with longer axis W. by S. Another of grey granite a little below summit level (1075 feet) with longer axis W.N.W. ($7 \times 6 \times 3$ feet). It stands very oddly, not resting on its wide surface of 6 feet, but on its narrow edge of 3 feet. Another boulder $12 \times 6 \times 6$ feet at 918 feet level, with longer axis N.W. by W. Another $12 \times 6 \times 5$ feet, with longer axis N.N.E."

The boulders just mentioned are situated along the flattish valley lying between Craig Dhu and Craig Coimichte on the south side, and Craig Willeim on the north side. This valley runs in an east and west direction, so that it is most probable that the boulders, almost all of which lie with their longer axis in the same direction, have been put into that position by the agency of a stream of some kind which flowed through the valley from the west.

It was through this valley that the Lake of Glen Roy, when it stood at the middle shelf, discharged. But it is not probable that the stream from that lake would have had power to bring these boulders, or put them into the positions they occupy. The boulders, moreover, are above the level of the stream.

In Glen Gluoy there are several boulders which deserve notice. Glen Gluoy is the narrowest of all the valleys, with sides high and steep. There is a boulder $9 \times 8 \times 6$ feet, on the hill which separates Glen Fintec from Glen Gluoy. It is at a height of 812 feet above the sea. The hill here slopes towards W.S.W. at an angle of about 45° . There is a thick covering of drift on the hill above, and immediately below, there is a striated rock. This boulder must have been brought here from the west by some agent, such as floating ice, which stranded on the hill.

At another spot there are several large boulders, also on a steep slope, at a height of about 866 feet above the sea. They stand up somewhat conspicuously above the drift in which they are partially imbedded.

How came these boulders into this position?

1391

See not lake

I can see no better explanation than this, that originally these valleys had been filled up with drift, and that the same agent which spread the gravel, brought the boulders. At this time there was an open kyle or passage at the head of Glen Gluoy, and through which a current could pass. After the sea subsided to a level below 1000 feet, a lake was formed here, as in other glens; and as these lakes subsided from one level to another, much of the drift was washed away, leaving the boulders exposed, and putting them into positions which they had not originally.

Several boulders were noticed by me, standing in a very *unstable* position. Thus, there is one on the south bank of Loch Treig, as shown in fig. 16 (page 630). A is a bank of detritus, the top of which is about 40 or 50 feet above the lake B. The upper part of A consists of white sand, horizontally stratified, formerly a bed reaching back to the rock of the hill C, distant about 50 feet. The breadth of this sandy plateau may be about 30 feet. It is broken down by rabbits next the lake, whereby a depth of several feet of sand is exposed. The boulder D stands upright in the sand bed, about 5 feet above its surface, and is about 2 feet thick. How much of the boulder is buried in the sand-bed I had not time or means to discover. Its appearance suggested the idea that it had been floated on ice, and slipping off with one end foremost, sunk into the sand, then the bottom of a lake or sea.

In reference to the direction of that general movement which seems to have passed over this district, causing a transport of boulders and gravel, one or two specific facts may be added.

In the Ault Laire valley, situated about a mile to the west of Loch Treig, I found a number of red porphyry boulders. Several boulders of the same rock I found on Craig Dhu and Craig Coinnichte. I see that Mr JOLLY supposes that these may have been brought by the Loch Treig glacier. I am not aware of any rocks of that description being *in situ* in any part of Glen Treig; but they exist on Ben Nevis. I saw them there *in situ* on the east side of that mountain.*

The next fact which I mention was made known to me by the late Mr ANDERSON of Inverness, a geologist of great intelligence and experience. He informed me that among the gravel of the hill of Torvane, situated at the east end of the Great Glen, there are numerous pebbles and boulders from a conglomerate rock existing *in situ* near Fort Augustus (30 miles to the west).

There is a huge boulder on the hill situated on the north side of the Linnhe Loch, opposite to Fort-William. It is on the west side of the hill, and at a height of 1494 feet above the sea. It appears to have been brought from the

* Mr JOLLY informs me that red porphyry rocks occur on the hill called Ben Dearg, so called from its red colour. Ben Dearg is distant some miles from Glen Treig, to the west.

N.W. across a deep valley. ("Proceedings of the Royal Society of Edinburgh" for 1872-3, p. 162.)

At the east end of the Great Glen of Scotland, on the hills and elevated plateaus west and south of Inverness, there are large boulders of a coarse granitic conglomerate, whose parent rocks are situated to the W.N.W. In the district where Lochan Clachan is situated (about 8 miles S.W. of Inverness), the striations on the rocks are due E. and W. On one of these rocks so striated (at a height of 1259 feet above the sea) lies a large boulder, with its sharp point towards the *west*. Its broad end lies against a portion of the rock, which has prevented its further progress *eastward*.

On the hills adjoining, there are numerous boulders, mostly on gravel drift. One boulder, of large size, and visible at a great distance off, is situated on the ridge of the highest hill in the district, about 1100 feet above the sea. It is called the "Watch Stone." It is also a coarse granitic conglomerate. Its position could not have been reached except by coming in a direction between W.N.W. and W. by N. (See Appendix.)

A very difficult question, as it appears to me, remains to be solved, regarding the agent which affected the smoothing and striation of the rocks in Lochaber and elsewhere in Scotland. Those who have preceded me in this "Parallel Roads" inquiry have referred to it, and I cannot pass it unnoticed.

On one point most geologists are agreed, viz., that the detritus spread over the country, and reaching to our highest hill ranges, is *in situ*.

Even Dr MACCULLOCH, in whose day so little was known about these matters, inferred from the facts which he saw, that "portions of the lines (or roads) have been formed in a *rounded* and *transported* alluvium of pebbles, sand, and gravel. We suppose that a *rounded alluvium had been by previous causes accumulated in the glens. If this took place from the action of former waters flowing through the valleys (and to what other causes can we assign it)*", &c., p. 389.

DARWIN, who maintained the marine origin of the Parallel Roads, founded his strongest argument on the undoubtedly marine character of the detritus, on which these "Roads" had been impressed.

Professor NICOL, of Aberdeen, in his paper on the Parallel Roads, refers particularly to the "detrital cover," in which he says "the lines are cut;" and adds, "that it is a *marine deposit*, seems beyond doubt," p. 283.

Mr JAMIESON describes the thick beds of stratified clay, sand, and gravel, in various parts of Perthshire and Aberdeenshire up to about 2000 feet above the sea, as *apparently marine* ("Lond. Geol. Soc. Jour.," vols. xvi. and xxi.). He considers that it was "during this submergence that the brick clays containing arctic shells were deposited, and that boulders were drifted here and there, by floating ice," p. 194, vol. xxi. In a previous paper (vol. xviii. p. 164), the same author was on this point still more explicit. "At the bottom

*2000 feet
apparently
marine*

of all the drift beds, there is in our northern latitudes a phenomenon, which, if rightly understood, would dispel much of the obscurity that still envelopes the history of that period—I mean that *curious scoring and polishing of the rocky bed, on which the drift is found so frequently reposing.*”

On this point, therefore,—viz., the marine origin of the detritus,—there is a general agreement. But how about the smoothing and striation of the rocks beneath the detritus?

Professor NICOL and Mr JAMIESON ascribe these effects to the action of land ice,—not so much to local glaciers, as to glaciation of a more general character.

Professor NICOL thinks that the rocks were smoothed and striated during “*the general glacial striation of the land.*”

Mr JAMIESON thinks that these effects were produced during “*the great land glaciation of Scotland.*”

CHAMBERS entertained the same view.

These authors adopt the idea that, before the submergence of the land, the rocks had been ground down, smoothed, polished, and striated, under the operation of a great ice sheet which covered the country, as such a sheet now covers Greenland.

According to that view, there could have been no detritus when the rocks were thus acted on. Professor NICOL on this point is explicit. He says that the “*detrital cover has been formed, since the general glacial striation of the land.*” This (he says) “*is also proved by the fact that it spreads over the rocks marked in this manner.*” “*In Glen Roy, these striated rocks occur immediately under the lines.*” “*The old line or parallel road now passes over the rock surface, that in a former period was worn and striated by the glacier.*”

This point, that the detrital cover, in which the Parallel Roads are cut, lies directly upon the striated rocks, is one of some importance with reference to the cause of striation. I therefore add one or two extracts from my own notes. “*Found a flat on which Roman Catholic Chapel stands, about 100 feet above Bridge of Roy Inn. At this place, smoothed rocks with scratches on them. Some of the faces of these scratched rocks horizontal, others nearly vertical. They rise up abruptly from the flat. They are covered with sand and gravel*” (Notes, vol. i. p. 3). About 500 yards to the north of the summit of Craig Dhu, found *smoothed rocks, covered partially by detritus* (Notes, vol. ii. p. 42).

In farther illustration of this point, I give a diagram of a smoothed rock (fig. 17.) at the side of Shelf 4, covered by drift, except where exposed. The idea suggested on the spot was that the boulder, as well as the rock, had been originally entirely covered by detritus; and that the detritus being removed by the water of the lake, the boulder and rock were left exposed. This rock

had formed an angle or projecting point when the lake existed. The old beach, viz., Shelf 4, goes round the rock.

JAMIESON, in like manner as Professor NICOL, maintains that whilst the "drift beds" repose on the scored and polished rocks, the rocks were scored and polished while the land was covered with ice, the drift beds being deposited during the subsequent submergence of the land. (Vol. xviii., p.164.)

The question is, whether the ice-sheet alone could have polished and scored the rocks in the peculiar positions in which they are sometimes found. Had these smoothed and scored rocks been generally on the tops or ridges of hills, there would have been less difficulty in ascribing these effects to a general ice-sheet. But instead of being in these exposed positions, the smoothed and striated rocks are most frequently in valleys :—and the narrower the valley, the

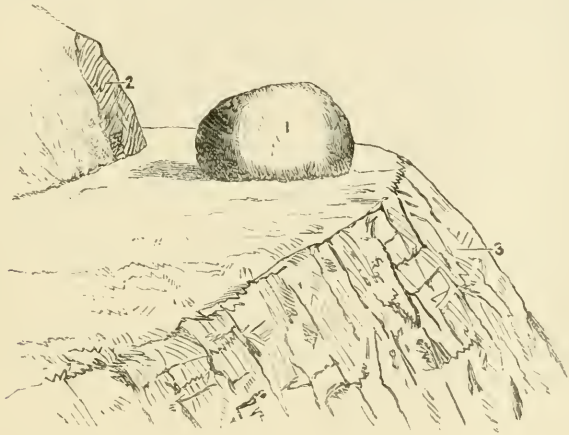


Fig. 17.

1. Gneiss Boulder, 8 feet high, 48 feet round, on Shelf 4, above Inverlair House : shelf here about 60 feet wide. 2. A rock smoothed by some agent. 3. Gravel stratified, on which the shelf was formed, forming a steep scarp about 50 feet high.

more remarkable is the smoothing and polishing. This is undoubtedly the case in Glen Spean, at its narrowest parts between the Roman Catholic Chapel and Inverlair.

It appears also that the heavy body which effected the striations was, when obstructed in its passage by a solid rock, capable of rising over it.

Now what would happen, when a body of land ice was so obstructed ? If the rock did not break, the under part of the ice would probably be arrested, and the upper part would, under the influence of the propelling force, move on.

On the other hand, in the case of a body of ice floating, the buoyancy of the ice, when obstructed, would enable it to rise up and over the obstruction.

There is another difference between the two cases, favorable to the theory of floating ice. The detritus covering the sea-bottom, would afford to floating ice means of smoothing and scoring. But as the ice cake period is supposed to have *preceded* the detritus period, the land ice in passing over the rocks would have no such help.

There are other circumstances which favour the idea of floating ice, suggested by some observations by Mr. JAMIESON himself.

He mentions having noticed, at considerable heights both at Loch Treig (vol. xviii. p. 172) and in Glen Roy (p. 177) striæ running *horizontally*, on the rock *faces*.* I made a similar observation on Craig Dhu.† Mr JAMIESON also takes notice of the circumstance that on Craig Dhu, “the largest and most angular blocks are more numerous high upon the *very brow of the hill*, at a level of from 130 to 400 feet from the top, than they are farther down” (vol. xviii. p. 175).

Similar observations were made by Mr DARWIN and others.

There is another feature in these Glens, pointing to floating ice. I allude to the discovery of exceptional lines of detritus, running nearly horizontal on the sides of Craig Dhu and Ben Chlìnaig, where they face each other, and also on the sides of Glen Roy. These lines are at different heights, from 1200 to 1700 feet above the sea. Mr JAMIESON says of the Ben Chlìnaig lines, “I ascertained that these short lines were neither quite horizontal nor perfectly parallel. I therefore think they “have arisen from *some other cause* than what formed the Parallel Roads.”

Mr JOLLY concurs with Mr JAMIESON in stating “that these lines are not absolutely horizontal. They rise and fall in short distances on the hill side, gradually but perceptibly” (MSS. p. 15).

Mr JOLLY adds, that these banks “form a rounded curve like that of a mound or ridge, laid upon the hill. They resemble “kaims” in the outline, and present the appearance which ridges of detritus would have if deposited on a slope. Between them and the hill, there exists a hollow, often deep enough to form a kind of valley. This moundy character is well seen on all the lines on Ben Chlìnaig, and Craig Dhu” (MSS. p. 13).

Mr JOLLY is decidedly of opinion that these banks are moraines; Mr JAMIESON had previously indicated an inclination towards the same view. ROBERT CHALMERS felt assured that they were sea-beaches, and entirely of the same class as the Parallel Roads.

I have the misfortune to differ from all these views. I think that Mr

* See p. 41 hereof.

† See p. 640 hereof. For an interesting account of the agency of Pack Ice, not only in transporting boulders, but in making “horizontal grooves and scratches” on cliffs of rock, see a paper by Professor JOHN MILNE, F.C.S., in the *Geological Magazine* for September 1876.

JAMESON suggested a theory nearer the truth when he asked "Might not some of these curious accumulations known as *Eskars*, *Osar*, and *Kaim*s, have been formed by a re-extension of the ice ploughing into the old marine beds, and forcing them up into long narrow mounds? In some regions, these may have arisen from glaciers terminating in the sea." (Vol. xix. p. 253.)

The only modification I would presume to make on this suggestion is, that instead of glaciers pushing into the sea, and "ploughing the marine beds into long narrow mounds," I would suppose that icebergs, floating through Glen Spean and grating on Ben Chlìnaig and Craig Dhu, might have produced the long ridgy kaim-like mounds referred to.*

If it be generally agreed, that the land was *submerged*; that the beds of gravel and sand spread over the country are *marine*, and that many of the boulders (especially those on hill tops) cannot have been transported except by floating ice, it seems to me more philosophical to use that acknowledged agency, for the explanation of other phenomena of the same class (I mean the smoothed and striated rocks), than resort to a different agency altogether, whose existence is, to say the least, very problematical.

Before concluding, let me shortly state the views I have taken in this Memoir, both on the local question of the Parallel Roads, and on the more general questions into which I have been led.

1st. The valleys in which these roads occur have been occupied by lakes which subsided from one level to another, as the blockages of the lakes were worn down.

2nd. These blockages consisted of detritus (clay, sand, and gravel) which had been spread over the country when it was submerged, and which filled all the valleys, up to considerable heights.

3rd. The blockages were from time to time worn down, and the materials composing them removed by the action of rivers, the cutting power of which would increase as the sea sank from its original high level to its present level.

With regard to the more general question it would appear—

1st. That before these Lochaber Lakes were formed, the whole country had been under the sea, and that during this submergence, currents with floating ice spread gravel, sand, and clay over what was then the sea-bottom, filling hollows on what is now the land, and causing rocks to be smoothed and scratched by the passage and pressure upon them of stones and pebbles.

2nd. That the sea prevailed to a height of at least 3000 feet above the present sea-level.

* It is not unimportant to observe that all these abnormal lines, in Glen Spean and Glen Roy, are in level above the highest of the "Parallel Roads." The sea may have formed these lines at a period antecedent to the formation of the lakes. The lakes, of course, could not be formed till the sea had sunk to a level below the highest shelf.

3rd. That the direction in which this current flowed over this part of Scotland was from the W.N.W. (magnetic), judging by the transport of the gravel and boulders, and also by the markings on the hills and rocks; but that this direction was modified by the hill ranges and submarine valleys over or through which the current passed.

A P P E N D I X.

The statements in the text as to the existence of a sea with floating ice, in which a current from the N.W. prevailed, receives remarkable confirmation from the direction of the striations on the hills of Ross and Argyleshires, as observed by the late ROBERT CHAMBERS. In a paper read by him before this Society, in December 1852, he gives the following observations as made by himself:—

1. On Cuineag and Canish hills (in Ross-shire) at a height of from 1700 to 1800 feet, the striations run about N. 60° W.

To this general rule there are certain exceptions, caused, as Dr CHAMBERS shows, by the contour of the hills.

2. On a summit running S. from Ben More, fully 1500 feet high, four or five miles S.E. of Cuineag, there are streakings on the quartz, observing the normal direction, viz., about N. 60° W.

3. On the Gneissic platform, between Coal More and Sulvean, there are polished surfaces striated between N.W. and W. To the west and north of the latter mountain there are similar markings.

These are situations where, in Dr CHAMBERS' opinion, *no local glaciers could have existed.*

4. Streaking, precisely the same, exists at an elevation of at least 2000 feet on the quartz mountain named Ben Fay, south of Loch Maree.

5. On free ground, between Garloch and Poolewe, there is similar marking with a direction from W.N.W.

6. So also is there, in the great elevated valley of passage across the island in Ross-shire, the Derry More.

7. North at Rhiconnish, there are *traces coming in from the coast, viz., from the north-west, and passing across a high moor, with no regard whatever to the inequalities of the ground.*

8. A little further north, at Loch Laxford, a fine surface is marked with striation from the N.W., *being across the valley in which it occurs.*

9. At an opening in the bold gneissic coast which looks out upon the Pentland Firth, there is strong marking from N.N.W.

10. The high desolate track called Moen, between Loch Eribol and Tongue Bay, where there is nothing that could restrain or guide the movement of the ice, exhibits striation from N. 28° W.

11. Striae N. 25° W. occur four miles to the east of Tongue Bay.

12. In Caithness there are traces of striation from points between N. and N.W., *being directly transverse to a line drawn from the neighbouring hills.*

13. In the Island of Kerrera, opposite Oban, and in Mull, striations are noticed pointing N. 60° W.

In all the above cases, the agent which produced the striations, came, in the opinion of CHAMBERS, *not from the hills in the interior of the country, but from seaward.*

Mr J. F. CAMPBELL of Islay, in a paper read by him in the London Geological Society (25th June 1873), mentions that the perched boulders on the hills of Tiree and Barra, as well as the striations of the rocks in these islands, indicate transport from the N.W. and N.N.W. He suggested an Arctic current from Greenland.

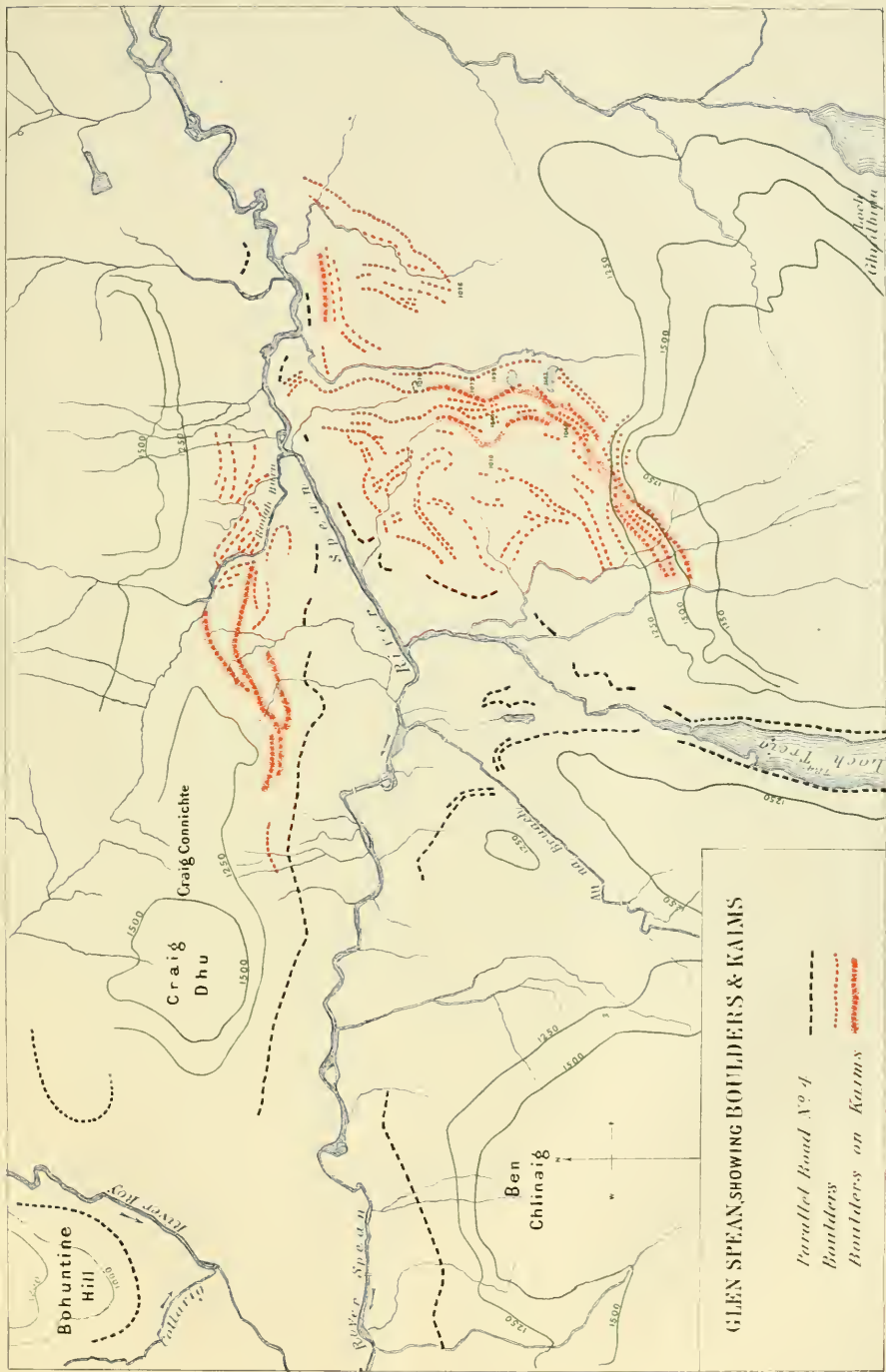
Dr BRUCE, LL.D., and Mr JOLLY, Inverness, have given similar testimony as to the direction of the agents which smoothed the rocks on the Long Island,—viz., that they came from the west, and not from the mainland of Scotland.

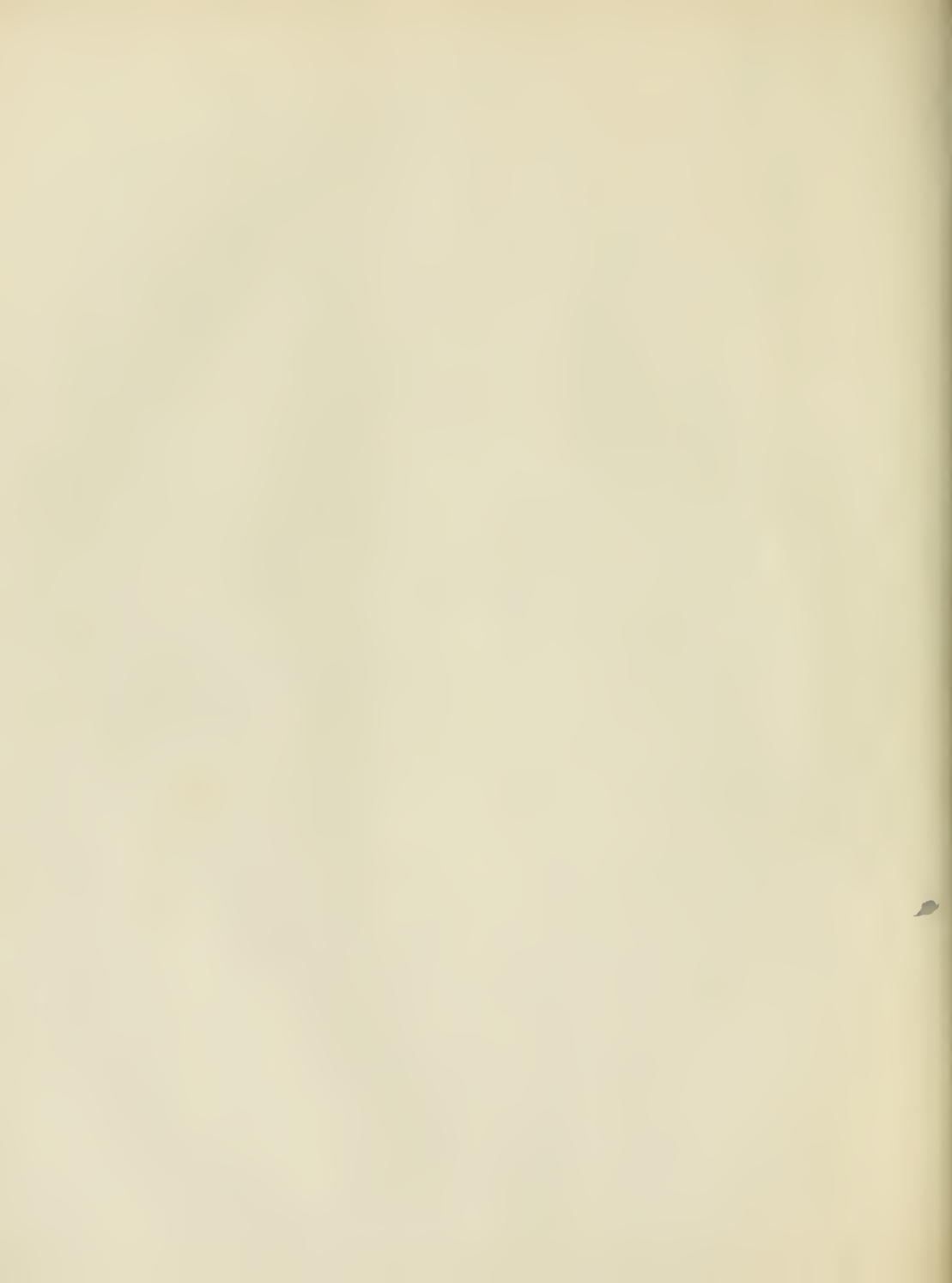
EXPLANATION OF PLATES.

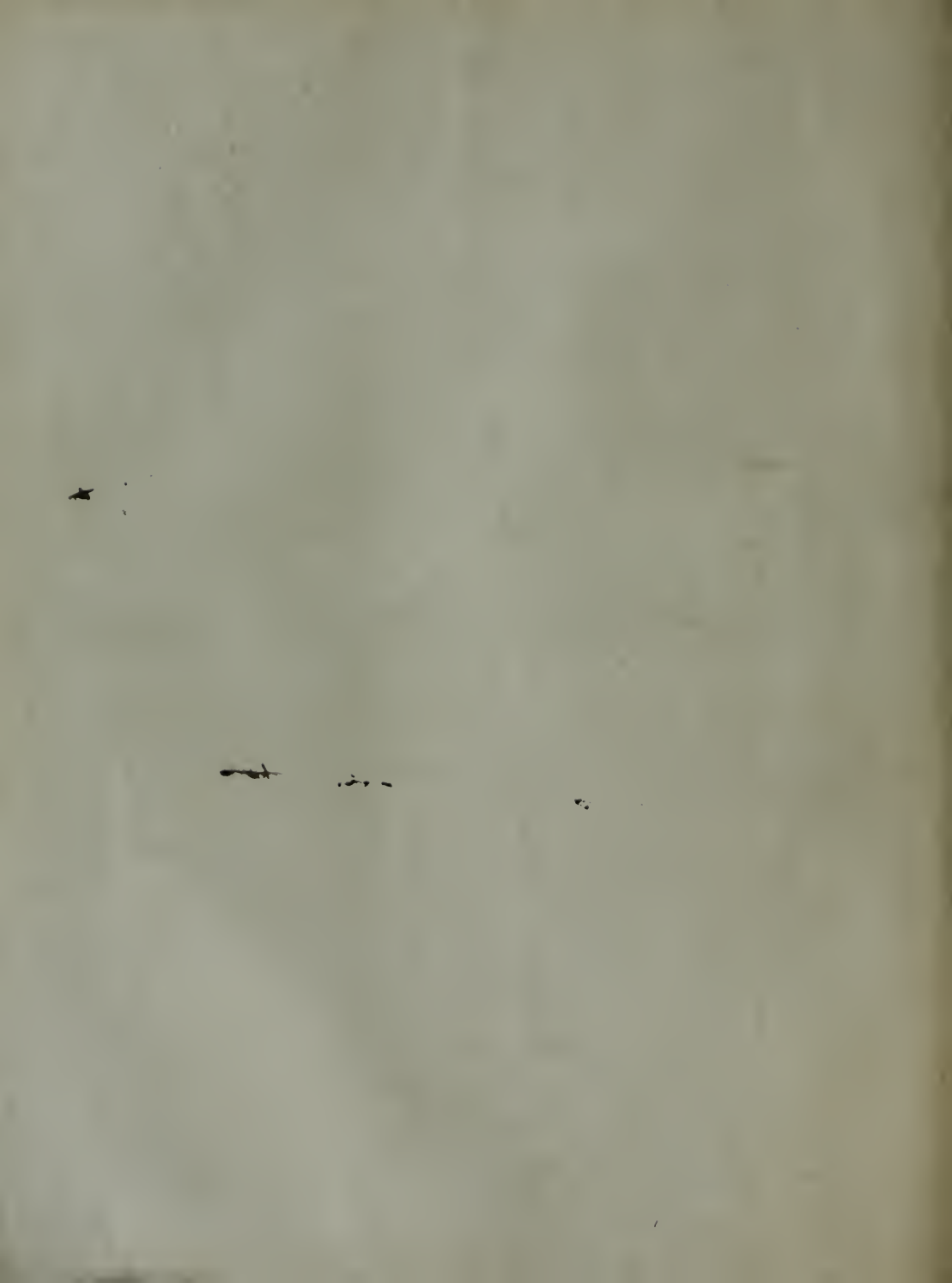
- Plate XLI. General Plan of Lochaber, showing all the Parallel Roads.
 Plate XLII. Plan of Glen Collarig, where Shelves 2, 3, 4 terminate.
 Plate XLIII. Part of Glen Spean, where Escars and Boulders abound.

LIST OF DIAGRAMS.

- Figure 1. Sketch from Turnpike Road at Tulloch, looking towards north side of Glen Spean, showing mounds of detritus which had formed part of bottom of the lowest Lake (Shelf 4), cut through by mountain streams. Referred to p. 598.
 Figure 2. Plan of Escars in Alt-na-Bruach. (Text, p. 602.)
 Figure 3. Section of Escar in Alt-na-Bruach. (Text, p. 603.)
 Figure 4. Lower end of Loch Laggan, showing old bottom of Lake (Shelf 4) cut through by River, now discharging from it. (Text, p. 606.)
 Figures 5 and 6. Plan and Section of Invergussern (in Text, p. 608.)
 Figures 7 and 8. Plan and Section of old Lake near Monassie, (in Text p. 609.)
 Figure 9. Glen Gluoy, its two Shelves, to explain why higher Shelf reaches farther down Glen than lower Shelf. (Text, p. 610.)
 Figure 10. Glen Collarig; the blockage in it. (Text, p. 611.)
 Figure 11. Plan showing the position of the Kilfinnin Shelf. (Text, p. 613.)
 Figure 12. Loch Ness, part of, showing where detritus prevails most on its banks. (Text, p. 614.)
 Figure 13. Old River Cliffs on right bank of Spean. (Text, p. 617.)
 Figures 14 and 16. Plan and Section of two Shelves or Roads at mouth of Loch Treig. (Text, pp. 630, 631.)
 Figure 15. Section showing Terrace on South Bank of Loch Treig, with tall Boulder sticking in it. (Text, p. 636.)
 Figure 17. Shelf 4, near Inverlair, with Boulder on it. (Text, p. 645.)







J. P. Campbell Esq

From the author

23 Nov 1877

J. P. Campbell

Widely Lodge

Bensington

London W

Nov 28th

Returned through Doctor Cummins
my paper on this subject



